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THE SOCIETY FOR ECONOMIC BOTANY

On October 21, 1959, a meeting of the Council of The Society for Economic Botany was held in Washington, D. C. Among other items of business, the Council appointed a nominating committee to prepare a slate of candidates for the Society's first formal election. Plans were made to hold the first general meeting of the Society some time in the Spring of 1960. An ad hoc program committee was appointed and charged with developing detailed plans for time, place, and program for this first meeting.

The Council also appointed a Technical Editor and five Editorial Board members to give broad discipline representation to the editorial staff of Economic Botany, the official organ of the Society.

The pro tem Treasurer of the Society, Dr. D. J. Rogers, reported to the Council that as of October 21, 1959, the Society had 156 members, including four life members, one patron, and one Sustaining Member. Since that time, about thirty additional members have been registered. Geographical distribution of members is of interest. All areas of the United States are represented with the heaviest concentration of members in the Northeast, followed closely by the Pacific Coast states, the Southern states, and the Mid-West. Fifteen foreign countries have each contributed one or more members. Applications for membership continue to come in. Though formal application blanks are not required, these can be obtained from the pro tem Secretary, Dr. Quentin Jones, New Crops Research Branch, Plant Industry Station, Beltsville, Maryland.

Ecological Indications of the Need for a New Approach to Tropical Land Use

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Early Agricultural Systems

The stimuli for man's development of agriculture in prehistoric times probably were encountered in open areas of grassland, in the steppes, the prairies and the savannas. How agriculture actually came about may never be determined, but surely there must have been a logical sequence of accidental discoveries.

We may imagine incursions into the grasslands to hunt the plentiful game; the normal tendency persisting today in man to keep an occasional young wild animal when food was plentiful; and the early discovery of which could be domesticated and even thrive attached to man. Perhaps such animals were found to be useful as decoys to aid his nomadic hunting and it is not difficult to imagine his early discovery of the possibilities of milking and riding some of his domesticated beasts.

The supplementing of his meat diet with fruits and wild grains would seem to have led normally to the development of specific routing of his wanderings during harvest seasons, subsequent settling in the vicinity of rich areas of game and wild plant crops and eventually on to actual tillage in combination with the herding of domesticated stock.

Over the millenia from some such tentative agricultural beginnings, man has refined his agricultural techniques, crops and animals, prospered and multiplied himself manyfold and extended his domain into the far corners of the globe with all their varied climates.

The steppe-prairie type of agriculture was expanded early and successfully into the semi-arid and arid regions with the development of irrigation. This was again a logical development since there they found high fertility of the soils and the low successional pressure of weed growth could readily be controlled with hand labor and primitive techniques. Salinization and siltation were the main problems, but high productivity was attained even in early times (1). At Girsu in Central Iraq, records show that wheat yields in 2400 B.C. averaged 2537 liters or 72 bushels of grain per hectare as compared with the USA average in 1958 of 67½ bu. per hectare.

The same steppe-prairie type of agriculture was brought long ago to the tropical regions and in the Americas revolved primarily around the production of maize. Again the centers developed in and around the grasslands: the Mayan Civilization, the savannas of Mexico and Guatemala; the Chibchas, the savanna at Bogota, Colombia; and the Incas centered on the montane prairies and steppes of highland Peru. In the latter place, from the ecological point of view, we should look first of all for the natural ancestor or ancestors of maize. Conditions in such montane and lower montane belts of the tropics are quite similar in general climatic characteristics to the corresponding areas of the temperate regions.

It is perhaps significant that of these civilizations in the Americas in prehistoric times, the one that succumbed first, even before the arrival of the Spaniards, was

that of the Mayas. This civilization had extended itself away from the natural grasslands and into the forest and, in addition, was farthest removed from the steppe-prairie type of climate.

Along the road of agricultural development, man added tubers, fruits, other cultivated plants, more domesticated animals, and continued to select and refine the qualities of all these to better suit his needs and fancies. However, for the greater part, these were only supplements to enrich his life. He continued primarily with his steppe-prairie type of agriculture based on grain culture and the raising of domestic animals.

One other successful variant of agriculture in prehistoric times, which as with irrigation, permitted man to develop complex societies significantly removed from the steppe-prairie regions where potential evapotranspiration balances rainfall (2), was that of the wet-land rice culture combined with swine and poultry in southeastern Asia. This is of great interest to us because of its successful extension of agriculture into the lowland humid tropics. The density of population that such areas still support, largely with primitive techniques, locally developed systems of highly productive fish culture within the rice paddies and the permanency of this type of agriculture should all be of major interest to the investigator of tropical land use.

In part, such a system depends upon the high productivity of the water environment, an area of development of food resources only partially utilized by man to date. However, the apparently most significant fact connected with the successful wet-land rice culture, as with the case of irrigation in subhumid and arid areas, is that of the artificial control of the water table. These three types of grain-animal agriculture appear to be examples of the most productive land-use in terms of production of surplus food of a balanced nature or of the ability to support permanently a high population density.

Favorable Soil-Water Balance in the Permanent Systems

In the one case where agriculture probably originated, along the unity line of potential evapotranspiration, the downwards and upwards movements of soil water is exactly balanced. There, where the ideal water table exists, man has found little difficulty in maintaining the fertility and productivity of the soil. In moving away from the unity line towards more humid districts, agriculture encounters two problems gradually increasing in severity connected with the greater abundance of precipitation. One is the problem of surface erosion; the other, that of the leaching of nutrients downwards through the soil. Erosion control measures and use of commercial fertilizers to combat these problems, climatically speaking, soon reach their economic limitations.

Towards the arid zones from the unity line, the soils may be more fertile due to the predominant upward movement of water but the lack of water becomes a limiting factor, as does both surface-water and wind erosion. Even fallow systems of crop culture soon reach their limits and the slow regrowth of protective vegetation makes erosion control a serious problem.

On the arid side, the use of artificial irrigation permits man to move into the driest areas where suitable soils, adaptable topography and water for irrigation are available. The high fertility of the soils can produce excellent crops for the feeding of man and his live-stock, but the system is predicated on the existence of a complex stable social organization for the establishment and maintenance of the irrigation installations and great attention must be paid to the water table level to avoid salinazation as well as to silt deposits which alter ground levels appreciably over the centuries.

In the wet-land rice cultivation system, erosion is limited by the development of flat, dike-enclosed fields, and leaching

downwards in the soil stopped by a puddled-clay bottom to the field. Thus, the cultivator eliminates the main problems of humid climate agriculture and through his drainage ditches and irrigation canals maintains complete control of the water levels. Located as the system is in humid regions, the construction of irrigation canals is less complex and the agricultural system functions well within a simple, reasonably stable social structure.

Other Agricultural Systems in Tropical Regions

All three of the above stable types of agriculture were applied with satisfactory results within the tropical belt even in prehistoric times. Nevertheless, because they were limited to certain climatic, topographic and social conditions—and in the case of wet-land rice culture never discovered in the western hemisphere in prehistoric times—the major portion of the tropical belt was and still is, under increasing population pressure, devoted to other types of agricultural land use or left largely idle. A brief examination of these other system of land use seems desirable.

The low-pressure, low living-level land-use of primitive hunting and agricultural groups is of little interest in terms of food production and population support. Unless specially protected, these groups disappear in the face of pressure from more dynamic land-use systems.

The wide-spread system of shifting cultivation under low population pressure is a perfectly satisfactory system of tropical agriculture based on a rotation of short-period, agricultural cropping followed by the redevelopment of natural vegetation over a long period of years during which the fertility of the surface soil is built up again and competing weeds, such as the grasses, are eliminated. The shifting cultivation system, however, is far from intensive and supports only a small population at a relatively low level of living. The labor involved in new land clearing at frequent intervals restricts cultivation to a low acreage; there is usually no surplus to pay for roads, schools, and similar services, and the products must remain locally for subsistence only. Thus, this system offers little or no prospects for the development of intensive permanent agriculture. The major item of interest in the system is the power of the tree growth to restore the soil to good condition. Where market conditions justify timber production, such a system may be converted more profitably into forestry land-use with the long part of the rotation in the growth of a timber plantation and the short period changed to the "taungya" system of tree-plantation establishment, with intercropping to reduce early plantation establishment and tending costs.

Less conspicuous and often partially developed in conjunction with other systems is the permanent subsistence plot around the homes supporting a mixture of fruit trees, bananas, vines, shrubs, and other food producing plants. Such agricultural land use is interesting in that it most closely approximates the physiognomy of the forest, and although statistical data on production are practically nonexistent, there is no doubt as to the permanence of productivity and probably a quite high production in terms of food value. As with the wet-land rice agricultural system, this is also often tied up with the production of hogs and chickens.

Within historic times and more or less paralleling the development of guild craftmanship and industrialization, the great push in tropical agriculture has been that of the plantation system, the system of large land holdings producing one or at most only a few products for export from the area or region. Originally set up with slave labor it has largely persisted, even long after emancipation, in maintaining the general appearance of a feudalistic system of rich owners and a large number of workers at a much lower living-level status. Even where paternalistic

companies or owners pay good wages, the dependence on the owners, the monotony of company settlements and the unavoidable regulation of life even outside of work hours seems to inhibit the development of the folk-loric modes and community activities which are an essential part of man's needs for contentment.

In one sense, plantation agriculture may be considered an economic or land tenure system to be compared with subsistence or small-holding agriculture rather than an agricultural system to be compared with wet-land rice culture or shifting agriculture. Such an argument is strengthened also by the fact that the plantation system may use any of the basic agricultural systems such as irrigation in subhumid or arid areas. However, the system is considered here briefly as a land-use system because it brought in the practice of large scale production of products such as fibers, rubber, coffee, and similar crops, which could not be consumed locally as a balanced diet, and depends for stability on exchange rates and steady markets.

The latter point brings up one of the basic problems of plantation agriculture. Although large scale production theoretically offers the advantage of more efficient and more technical administration, its welfare depends on far distant markets catered to by plantations in many countries and even widely separated continents. When abundant land was available, workers owned outside the plantations or were furnished subsistence plots so that bad market conditions could be weathered readily. With the intensification of the plantation system within an area or country, poor marketing conditions can become critical to regional or national stability.

Apart from the socio-economic aspects of the plantation system, its success or failure as a permanent agricultural system has depended on the relation of the crop and crop-culture to the environment. Thus, sugar-cane in the sub-humid lowland tropics with irrigation, a grass crop in or near a savanna climate and rubber in the humid lowland tropics, a tree crop in a forest climate have been very satisfactory on a long term basis. Other plantations like the open-grown coffee of Brazil in a tree climate have not developed permanency and have moved continuously, as with shifting agriculture, although slower, from depleted to virgin soils.

Thus, the plantation system is obviously still in a process of evolution. The advantages of the system plus the growing exchange of information and tendency towards the formulation of production agreements between regions and countries indicate that it will persist. However, much improvement in the socio-economic relations between owners and workers must be worked out and better balances are needed as to diversification of crops within the individual plantations and between the percentages of plantations, small holdings and subsistence plots within individual countries or districts. Further, the plantation system must be considered as an economic type of farming or land-tenure and the actual land-use made to conform with a cultural system able to produce large product volume efficiently on a permanent basis.

Appraisal of Tropical Productivity Potential

Appraisal of the efficiency of tropical agricultural systems is very difficult, takes many distinct forms and occasionally gets far distant from reality. Production under the plantation system due to the interest in the products by industrial nations, ready convertibility to currency values, and more readily procurable statics, normally gets much more attention than subsistence crop production. Productivity of tropical soils is often compared unfavorably with temperate zone soils by the use of cool climate crops, such as maize, for a measuring stick. At any rate, productivity and efficiency of systems are usually compared with the production of the steppe-prairie agricultural system. Under such a comparison tropical agricul-

tural systems and productivity do not stand up well and the general low levels of rural life in tropical countries appear to bear this out.

The questions naturally arise as to whether tropical climates and soils are generally less productive than their temperate counterparts; whether the crops are inefficient producers or are poorly utilized, and finally, whether or not satisfactory agricultural systems are being employed for crop production.

The fairest method for comparing site productivity between life-zones or regions would seem to be that of total production of dry matter per unit area per unit time, as per hectare per year. But figures are not available generally for such comparisons. Possibly, however, satisfactory indications of relative productivities, may be determined indirectly.

The leaf measurements being carried out by Humberto Tasaico may have considerable value in that connection (3). I had found previously an average tree species leaf-length of 2.5 cms. in the Montane belt on Turrialba Volcano and had hypothesized that this would increase geometrically down through the altitudinal belts to 20 cms. in the tropical lowlands. Tasaico has found a 19.6 cms. average using 100 species in the lowlands at Sarapiquí, a ratio of 1 to 8. Interestingly too, the number of tree species in the climatic association of the Montane Wet and Tropical Wet Life Zones appears to vary in the ratio of 1 to 8.

While in Maine last summer, I measured leaves of all the trees species I could find around Alton and found an average length of 2.5 cms. for those which retain their leaves all year and 7.5 cms for those which last only during the growing season. Since the growing season is about 4 months or 1/3 of the year, the 7.5 cms. converts to 2.5 on a comparative 12 months basis. The forest in Maine falls in the Cool Temperate Region comparable to our Montane belt in the tropics.

Tasaico found that the individual leaf area probably varies between the Montane and Tropical Wet Forest Life Zones in the ratio of 1 to 64. The average width was very close to 40% of the average length in each of the two zones which would indicate that area varies according to the square of the length. In addition to average leaf size, trees are taller in the tropical lowlands than in the Montane Belt and the forest is made up of more strata. Measurements of timber tree growth show that, in general, increment is much more rapid in the tropical lowlands than in the Cool Temperate Zone. All this would seem to indicate a ratio of production potential of at least 1 to 4 and possibly of 1 to 8.

Now this luxuriant high tropical forest with its high potential of productivity has been developed by evolution over the millenia. By means of a tremendous leaf area, the interception of a considerable portion of the rainfall and a very rapid nutrient cycle, the forest makes full use of the climatic characteristics even with a very shallow layer of humus and nutrients in the top soil. Hardy and others have written of this cycle which apparently permits no greater loss of fertility through leaching than becomes available concurrently with the break-down of the parent material of the soil (4).

When man replaces the highly productive wet and moist tropical forests with a low crop such as maize or pasture grasses, the soils rapidly deteriorate in productivity except where there are alluvial lowlands with a high water table to prevent leaching or where an occasional flood deposits new silt on the area. The steppe-prairie system of agriculture can not even begin to realize the potential of these very distinct life-zones and, even when applied, produces satisfactory crops for only a few years at most. Much more favorable results are obtained with plantations of tree crops such as rubber or cacao with shade which in structure resemble somewhat the original forest.

Need for More Efficient Land Use

In the present generation, we are face to face in the tropical region with not only a very rapidly increasing population pressure, but also a population which desires a better material living level than that of low relative wages or low subsistence. The more easily managed soils with respect to fertility and nearness to the unity line of potential evapotranspiration have largely been occupied already. We must now turn more and more towards the areas of higher rainfall for new lands at the same time that we try to build up production on occupied lands. Then, during the next few generations, we must not only increase food production to meet the needs of the expanse in population but also increase the total productivity of the rural tropical worker so that levels of living may be raised rapidly. Through such progress, there is hope of attaining to a general educational level sufficiently high to lead to stabilization of future populations and the establishment of an ecological balance between man and his environment.

With the thousands of years of agricultural experience behind us and with all the benefits of modern scientific knowledge at our command, we should be able at this time to set forth a program to attain the desired results. On the contrary, with all the various technical assistance agencies in operation, with a new group of national technicians coming into being, and with a general awareness and desire to improve existing in government and private circles, we are confronted with actual statistical data showing us that we have lost ground in the race between production and population growth since the prewar period (5). This all indicates the need and desirability for a different and more effective approach to tropical land-use.

Land Classification

The first and most urgent need is for adequate land use classification maps which can indicate the potentialities of all areas so that efficient programs for colonization, road-building, extension, investigation and related development programs, may be outlined. We must stop the present trial and error methods so wasteful of human and natural resources which are the general rule in the tropics today. Our rough formation or life-zones mapping gives only a general idea of potentialities even though it is a correct start. This needs to be refined and extended to the association level where classification of edaphic and atmospheric factors may lead to precise specifications and planning of land use.

One of the profound benefits to be obtained from such a classification would be the clear-cut demarcations of agricultural and forestry areas. We are wasting tremendous quantities of human and technical efforts in trying to develop agriculture in new areas which can only serve man effectively in permanent forest, as well as in trying ineffectively to improve or salvage agricultural communities which previously have been established erroneously in areas also only suited for forestry land use.

Not only does such misdirected land use create severe economic and social problems which can not be solved by agricultural research, extension, or sociological studies, but at the same time it robs man of the productive potentialities of such areas for permanent productive forestry uses. Once the original forest is removed and the site deteriorated the restoration of such an area to its proper destiny as a productive forest requires a great amount of time, effort and expense. Tropical agricultural experts must learn that there exist potentially profitable land-uses other than those of crop-production and animal grazing alone. The high level of living in such countries as Sweden has been attained principally by the maintenance and proper management of forest on forest land. With our tremendous acreage of true forest lands in Latin America and with a tree growth

rate several times faster than that of Canada, Sweden and Finland, we are missing a sure bet by not giving the necessary attention to how good forest land-use management could assist in raising production levels and eliminating some of the agricultural slums now existing or in the process of being created. On the contrary, as Tom Gill recently stated (6) the several million dollar program of ICA, places forestry down in an obscure corner of their organization chart under Miscellaneous crops, with peanuts, prunes and Pepsi-Cola.

A clear demarcation of permanent agricultural and forestry lands is only a start towards good land-use planning. Within the area of lands suitable for permanent agriculture, too common inefficiency of production occurs due to the growing of tropical plantation crops in life-zones where such crops are far removed from their optimum growing conditions. Examples of these are sugar cane grown in the wet highlands and cacao grown in the subhumid tropics with irrigation. The resulting low economic production per unit area and per man-day help to maintain the myths of low productivity of the tropics and the impossibility of paying decent wages to field hands.

Good land-use potential maps would indicate clearly the existing errors in present crop location and help to avoid the wasteful trial and error methods for finding the right crops in newly developing sections. In addition to their low production, misplaced crops also place an insidious overload on the below-minimum technical staffs of ministries, experiment stations and other technical organizations. Entomologists, pathologists and other technicians are called upon and try to cure problems which are basically due to attempted production of a crop far from its correct ecological environment. Thus, the time of productive scientists is being wasted on impractical corrective assignments when it should be applied completely to more constructive aspects of their respective fields. Perhaps the subject of optimum environment for crop production offers the agricultural economists their best opportunity or field at this time to make a genuine contribution for the improvement of tropical agriculture.

Some Problems of the Plantation System

Misplacement of crops is most prevalent under the plantation system, in which owners frequently pay more attention to market conditions and their own crop preferences than they do to environmental conditions. This is understandable when we realize that even with low inefficient production, the owner can make a good living wherever he has abundant cheap land and cheap labor at his disposal. Thus, correction of this aspect of the plantation system needs early attention, if we are to raise general living levels.

As previously mentioned, the plantation system offers many advantages, whether or not they are always realized, and merits much socio-economic attention to remove present deficiencies. In addition to the problem of crop misplacement, there is a need for greater diversification of crops where possible within individual plantations, as insurance against low-price market periods for a given crop.

This aspect, however, is tied up with the problem of labor residence on the plantation and complete dependence on the owner. These conditions remind me very much of the previous aspect of the textile mill towns in New England of similar, gloomy, monotonous housing, a depressed population and hard times coincident with market slumps. Just as there is a need to increase the efficiency and the earnings of the plantation labor, I would guess that there is a desirability of getting most of the laborers off the plantation after work to their own private homes or subsistence plots within communities of more varied interests, aspects and life. The study of plantation workers, in my estimation, offers a very

promising field of needed investigation in tropical rural sociology.

Agricultural Systems for the Future

The systems of agricultural land use offer another promising area for rapid improvement. As discussed previously, agriculture close to the unity line of potential evapotranspiration and in irrigated dry lands has proved its permanency over the millenia. These types of agriculture can be improved with genetic selections, improved methods of culture and other technical improvements and it is in such areas that technical assistance experts can most gainfully be utilized, since the systems are common to both the temperate and tropical regions.

The wet-land rice culture system with mechanization offers the possibility of stepping up grain production to the degree desired in the American tropics. One definite advantage of this culture is that it could utilize the moist and wet areas of which there is a surplus for agricultural development in the region.

A new or modified land use system is definitely needed for the family farm, colonist or subsistence farmer in the lowland humid tropics. The shifting cultivation system may be technically correct, but is a low-productive, wasteful system. The copying of a one-crop, plantation system on a one-family scale is also inefficient because it can not afford equipment for the techniques needed with a single crop and makes the security of the family too dependent on a distant market which they do not understand.

Ecology indicates that a mixed crop culture, simulating the natural vegetation as far as possible, may offer the best system for the one family enterprise, on most of the agricultural land of the humid lowland tropics. The permanency and probable high production of the mixed subsistence plot around the home has been mentioned already. However, such a crude beginning offers considerable possibility for refinement to a permanently stable and highly profitable land-use system. Even though the development of the highly complex natural associations through evolutionary processes took long periods of time, man's knowledge and research techniques should permit him to work out satisfactory combinations of crops in short periods of time.

The copying of natural association physiognomy would permit the maintenance of the nutrient cycle permanently without the use of commercial fertilizers. The mixture of several elements should eliminate largely the development of insect or disease problems. By combining this system with the shifting cultivation system or in a sense copying the natural process of succession following the opening up of the canopy caused by the falling of a large tree, the grower could combine small areas of annuals or short term crops in a continuous process of rotation even in a relatively small area.

As an example of such, a 9 acre plot in the tropical moist forest in Costa Rica once in working order, should produce the subsistence needs of one family and provide a cash income of over 5000 colones (about US $712) per year. A suggested combination of crops is laurel (*Cordia alliodora*) and pejibaye palms (*Bactris gasipaës*) as the dominant and codominant plants of the overstory. The understory could be of cacao with the possibility of ipecac ("raicilla") in scattered blocks as low ground cover. During the establishment or successional phase, rice or corn, manioc and bananas could cover the ground and provide subsistence and income during the establishment of the long term crops. Establishment would proceed at the rate of ¼ acre per year, which with 30 plots or 7½ acres would permit a rotation of 30 years. This leaves 1½ acres for the house site, garden and fruit-tree pasture. Perhaps it would be desirable to add one acre more to each plot for a communal 3 acre pasture for every 3 families to maintain a pair of oxen. In addition, to the subsistence and

cash plant crops, hogs, chickens and even a cow for milk could be maintained and would help balance the subsistence needs of the family.

The prime advantage of such a system would be the attainment of a permanent, profitable land use for sloping lands in the humid tropics. By including a large percentage in long term crops, the worker could handle a relatively large acreage since the major attention required is only that of harvest of products. With a considerable cash income, communities of such small holdings could develop local road and school systems and through their production and purchasing power contribute substantially to national development.

Further, we should not hesitate to try to devise radically new systems of agriculture to better utilize the indicated high productivity potential of the humid tropical environment. The system of mixed cropping discussed previously lends itself more readily to small holdings than to the large plantation. For the latter, a system is needed to assure permanency with non-arboreal crops in the humid zones where the main problems are erosion and the continuous impoverishment through leaching of the soil fertility.

Theoretically, these could be corrected if the water table could be maintained at a high level and the amount of precipitation falling on the soil reduced. The possibility suggests itself of using underground irrigation pipes to keep the water level up near the fertile topsoil occupied by the crop roots, thus eliminating the downwards movement of fertility. To control the amount of precipitation falling on an area is still largely beyond man's control, but new plastic materials used for mulching might be employed in the interception of a portion of the rainfall before it reaches the soil. Plastic sheets supported above the ground, to carry a large percentage of the rainfall off the fields directly and applied during only the two to four months of excess precipitation, could eliminate the problem of erosion and removal of fertility. The economics of the proposed system have not been investigated, but may well be feasible today by reducing the needs for commercial fertilization and by stepping up production. More than ever, we need systems to insure permanency, as short term prosperity followed by abandonment does not contribute to the advance of tropical agriculture.

Utilization of Products

As a final consideration, besides working towards better programmed utilization of lands for the correct crops and the use of correct agricultural systems in each life-zone association, there is a great need to develop better utilization of the enormous tonnage of material produced in tropical areas. In many cases, the foreign market purchases only a minor portion of the crop produced and the remainder is discarded without utilization.

Recent developments in industrialization of waste products, such as the conversion of raw materials to proteins by yeasts need to be adapted to tropical conditions. New lands are continually being cleared for low-productive direct grazing while we disregard by-product materials potentially convertible to livestock feed which could support very likely several times our present production from existing grazing areas.

Challenge of the Future

Time does not permit further expansion in this paper of the subject of tropical potentials through increased utilization of present production. Neither in a broad view does time permit man to fumble along with trial and error haphazard development of tropical land-use while efficient medical research advances the means for increasing man's life span and population so rapidly.

Ecology indicates that the tropical areas offer the brightest productivity potential of the world and that tropical countries

could enjoy high levels of living for dense populations. Since with increased numbers of technicians in local or technical assistance agencies, we are not making progress, there appears to be justification for a careful reappraisal of our long-enduring steppe-prairie land-use mentality and of the present methods of trying to devise corrective methods for low-productive systems. Beyond such a reappraisal, a new approach from the tropical point of view is urgently needed.

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Utilization Abstract

Castor Oil in Perfumery. When castor oil is subjected to high temperature, it is split into three fragments: undecylenic acid, heptaldehyde, and acrolein. Of these, only undecylenic acid is useful as such, but all three produce valuable perfumery aromatic substances.

Undecylenic acid, when treated with H_2SO_4 isomerizes to form gamma-undecalactone. This product has a powerful, persistent, sweet, fruity odor, and is used in jasmin and lilac compounds. Methyl, ethyl, and allyl esters of undecylenic acid produce various odors suggestive of fruits, useful as modifiers of floral formulations. Other fractions or modifications are finding acceptance as odors suggestive of roses, citrus, and other such scents.

Heptaldehyde from castor oil is useful in perfumes and soaps. It is a starting point in the production of a-amylcinnamic aldehyde, a product marketed by Givaudan under the name Buxine®. This product has an intense floral odor of the jasmin type. Other modifications of the heptaldehyde yield odors similar to coconut, or violet-lilac, or oil of rue, etc.

Acrolein, though typically manufactured as a synthetic, is another castor oil fragment. Although it is highly toxic (a violent lachrymator), the reactivity of acrolein is such that 800 derivatives have been produced from it. Allyl caproate, one of many esters, is recommended for pineapple flavors. The principal products from acrolein are produced through reactions of the Diels-Alder type by condensation with various doubly unsaturated hydrocarbons.

From castor oil, then, almost the entire range of odor types may be produced.

M. S. Carpenter in *The Givaudanian, April, 1959.*

Antimicrobial Activity of Vascular Plants*

Numerous surveys have demonstrated the wide occurrence of active antimicrobial substances in higher plants. The array of compounds with unique structures which plants produce has served as a stimulus to continued search for useful antibiotics. Reports referred to in the table indicate that active substances have been found in plants from 157 families.

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Plants have long held a leading place as a source of medicinal drugs, records of their use dating as far back as 4000 B. C. For centuries plants and herbs have been used in various parts of the world for the treatment of certain diseases. Yet a scientific study of plants to determine their content of antimicrobial material is comparatively new. This is probably because, although the concept of antibiosis is not new, the establishing of its practical value is rather recent. The "antibiotic era" began with penicillin and streptomycin. Probably one of the first and certainly the first large-scale screening of green plants to determine their antibacterial activity was that of Osborn at Oxford University in 1943 (133) who tested 2,300 species of plants and found 63 genera active against either *Staphylococcus aureus* or *Escherichia coli*, or both.

With the increase of interest in antibiotics came an increase of interest in plants as a potential source of antimicrobial substances. Numerous surveys of plants in various sections of the United States and in many countries throughout the world were carried out which have demonstrated the wide occurrence of active compounds in higher plants (4, 5, 10, 16, 40, 71, 112, 123, 124, 126, 133, 138, 157). Although most of the purified substances with antibacterial activity have been found to be toxic to animals and not competitive therapeutically with the prod-

* Invitational review article for Economic Botany.

ucts of microbial origin, the search continues. This is due in part to the possibility that an important naturally occurring antibacterial substance might be found in a common, easily grown green plant. The extensive search for antitubercular compounds in plants has provided a constant focus of interest. The bulk of this work has been carried out by Lucas and his colleagues at Michigan State University (11, 31, 41, 42, 55, 56, 119, 120, 167). The discovery of various antifungal substances in plants has aided in the understanding of resistance to decay in certain trees such as cedar (*Thuja occidentalis* and *T. plicata*) and to disease resistance in certain crop plants. Chemists have continued their interest in plants because of the array of compounds with unique structures which they supply.

I have attempted to prepare a comprehensive survey of the available published data in tabular form to furnish a usable reference for investigators interested in a continuing search for antimicrobial substances in the plant kingdom. The data included are from work with vascular plants, that is, the angiosperms, gymnosperms, and pteridophytes. Emphasis, of course, is on flowering plants and conifers, but several representatives of other gymnosperms as well as the pteridophytes are given, including ferns, horsetails, and *Psilotum*. Reports referred to in this paper show active plants from 157 families.

For ease of use, the plants reported active by various investigators are listed alphabetically by Latin binomial, regardless of systematic standing, in Table 1. The binomials are taken directly from the original papers and may not be in accord with latest taxonomic usage. All pertinent data are given in the columns following the name. These include family, antimicrobial activity, type of extract tested, plant part(s) extracted, and references to the work for detailed information on any given plant. For brevity, symbols have been used where practical. The legend explaining these symbols precedes Table 1. Plants found to be inactive in the tests used are listed alphabetically in Table 2. Inclusion in this list does not imply that the plant is definitely without activity. It is merely that the plant part used and the type of extraction resulted in no activity in the tests employed. Further work will show many of these plants to contain active compounds.

TABLE I

ANTIMICROBIAL ACTIVITY OF HIGHER PLANTS

LEGEND FOR USE WITH TABLE 1
(An "O" in any column indicates no report given)

Type of Activity	Type of Extract	Plant Parts
B+ —Gram + bacteria	Ac —Acetone	B —Bark
B— —Gram — bacteria	Al —Alcohol (not specified)	Bu —Bulb
F —Fungi	Alc —Ethanol	C —Corm
M —Mycobacteria	Alm —Methanol	Cl —Clove
P —Protozoa	Aq —Aqueous	E —Entire plant
Ph —Phage	+ —Acid	Ex —Exudate
V —Virus	— —Alkali	Fl —Flower
Y —Yeast	B —Benzene	Fr —Fruit
	C —Chloroform	L —Leaf
	E —Ether	N —Nut
	EA —Ethyl Acetate	R —Root
	EJ —Expressed juice	Rh —Rhizome
	PE —Petroleum Ether	S —Seed
	S —Saline	Sl —Seedling
	SD —Steam distillate	St —Stem
		T —Tuber

A

Plant Name	Family	Activity	Type of Extract	Plant Part Tested	Ref's
Abelia grandiflora	Caprifoliaceae	Y	—	L, St	124
Abies balsamea	Pinaceae	B+	Al, E	O	10
Abies religiosa	Pinaceae	B+	S	O	58
Abronia villosa	Nyctaginaceae	B+	EJ	E	71
Acacia adonsonii	Leguminosae	M	Alc	L	106, 117
Acacia seyal	Leguminosae	M	Alc	L	106, 117
Acalypha hispida	Euphorbiaceae	B+, B—	Aq	Fl, L, R, St	120
Acalypha wilkesiana	Euphorbiaceae	B+	Aq	L, R, St	120
Acanthus spinosus	Acanthaceae	B+, M	Aq	L, St	42
Acer ginnala	Aceraceae	B+, B—, M	Alc, Aq	St, L, S	42, 120
Acer miyabei	Aceraceae	B+	Alc	L	119
Acer nigrum	Aceraceae	B+	Aq	L, St	42
Acer pennsylvanicum	Aceraceae	B+	Ac, Alc	O	123
Acer platanoides	Aceraceae	Ph, B+, B—, M, V	Aq, Alc	L, St, Fr, Fl	42, 35, 36, 37, 41
Acer pseudoplatanus	Aceraceae	B+, B—, M	Alc, Aq	L, St	42, 171
Acer rubrum	Aceraceae	B+, B—, Y	Ac, Alc, —	L	123, 138
Acer rufinerve	Aceraceae	M	Alc	L	119
Acer saccharinum	Aceraceae	Y	—	L	124
Acer saccharum	Aceraceae	B+	Ac, Alc	O	123
Acer spicatum	Aceraceae	B+	Ac, Alc, Aq	O	123
Accrates viridiflora	Asclepiadaceae	B+, B—	E	O	16
Achillea millefolium	Compositae	B+, B—, M	Aq, —, E	L, Fl	10, 113, 40
Acorus calamus	Araceae	M	SD	Rh	27
Actinidia chinensis	Dilleniaceae	B+	Alc	L	119
Actinomeris alternifolia (*Ridan alternifolius*)	Compositae	B+, B—	S	Fl, L, St	16
Adenostoma fasciculatum	Rosaceae	B+, M	Alc, EJ	L	5, 41
Adenostoma sparsifolium	Rosaceae	B+, M	EJ	E	5, 71
Adhatoda vasica	Acanthaceae	M	SD	L	7, 61
Adoxa moschatellina	Adoxaceae	B+	O	L	40

Plant Name	Family	Activity	Type of Extract	Plant Part Tested	Ref's
Aegopodium podograria	Umbelliferae	B+	Alc, Aq	L, R, St	120
Aesculus hippocastanum	Hippocastanaceae	B+, B, Ph, V	Alc, Aq	Fl, Fr, L, St	42, 35, 36
Aethionema pulchellum	Cruciferae	B+	O	O	133
Agastache nepetoides	Labiatae	B+, B—	E	L, S	16
Aglaonema pictum	Araceae	B+	Aq	L	120
Agonis linearifolia	Myrtaceae	B+	Aq	Fl	4
Agrimonia eupatoria	Rosaceae	B+, B—	O	O	40
Agrimonia gryposepala	Rosaceae	B+	Ac, Alc, E	L, R, St	99, 86, 123
Agrimonia striata	Rosaceae	B+, B—	+, Ac, Alc, Aq, E	O	16, 123
Agropyron caninum	Gramineae	B+	O	L	172
Agropyron repens	Gramineae	B+	O	L	172
Agrostemma githago	Caryophyllaceae	B+	O	Fl	40
Agrostis alba	Gramineae	M	Aq	R	41
Ajuga reptans	Labiatae	B+, B—	O	L	171
Albizzia julibrissin	Leguminosae	Y	Aq, —	L, Fr	124
Alchemilla vulgaris	Rosaceae	Ph, V	O	Fr	35, 36
Aletris farinosa	Liliaceae	B+, M	Alc	E	41
Aletris lutea	Liliaceae	Y	—	Fl, L	138
Aleurites fordii	Euphorbiaceae	B+, B—, Y	+, —	L, St, Fr	124
Alisma subcordatum	Alismaceae	B+, B—	E, S	O	16
Allamanda cathartica	Apocynaceae	B+	O	O	133
Allamanda hendersonii	Apocynaceae	B+	O	O	133
Allamanda neriifolia	Apocynaceae	B+	O	O	133
Allamanda violacea	Apocynaceae	P	Aq	R, St	47
Allium cepa	Liliaceae	B+, B—, M, Ph	SD, EJ, E, Alc	Bu, S, Sl	35, 36, 42, 62, 66, 72, 112, 139, 160, 166
Allium peninsulare	Liliaceae	B+, B—, M, F	EJ	E	5, 71
Allium porrum	Liliaceae	B+	EJ	Bu, Sl	66, 168
Allium sativum	Liliaceae	B+, B—, M, F	Aq, EJ	Cl, E	17, 72, 139, 166, 133
Allium triquetrum	Liliaceae	B+, B—	O	E	133
Allium schoenoprasum	Liliaceae	B+, M	SD	Bu	62
Allium ursinum	Liliaceae	B+, B—	O	Fl, L, R, E	40, 168, 133
Alnus crispa	Betulaceae	B+	Ac, Alc, E	O	123
Alnus glutinosa	Betulaceae	B+, M, B—	Aq, Alc	L, St, Fl Fr	41, 42
Alnus japonica	Betulaceae	B+	Alc	Fr	119
Aloe chinensis	Liliaceae	B+, B—, M	Alc, Aq	L	55
Aloe salmdyckiana	Liliaceae	M	Alc	L	41
Aloe succotrina	Liliaceae	M	Alc, Aq	L	55
Aloe vera	Liliaceae	B+, M	EA	L	56
Alpinia galanga	Zingiberaceae	M	SD	Rh	27
Alpinia officinarum	Zingiberaceae	B+	Ac	R	92
Alsine longifolia (*Arenaria longifolia*)	Caryophyllaceae	B+	E	O	16
Alstroemeria aurantica	Amaryllidaceae	B+, B—	O	O	133
Alstroemeria haemantha	Amaryllidaceae	B+, B—	O	O	133
Althea rosea	Malvaceae	Ph	O	O	35, 36
Alyssum saxatile	Cruciferae	B+, B—	Al, E	O	10
Amaranthus retroflexus	Amaranthaceae	B+, B—	—	Fl, L, E	113, 55
Ambrosia artemisiifolia	Compositae	B+, B—, M	Al, Aq	L, R, S, St	10, 42
Ambrosia psilostachya	Compositae	B+	EJ	E	71
Ambrosia trifida	Compositae	B+, B—	E, S	O	16
Amelanchier canadensis	Rosaceae	B—	Aq, —	L	138

Plant Name	Family	Activity	Type of Extract	Plant Part Tested	Ref's
Ammorphophallus companulatus	Araceae	M	Al	St	64
Amphicarpa bracteata	Leguminosae	B+	B, E	O	10
Anaphalis margaritacea	Compositae	B+, B—	Ale, Aq, E	E, Fl, L, R, St	10, 42, 120, 16
Andromeda glaucophylla	Ericaceae	B+	Ac	O	10
Andromeda polifolia	Ericaceae	B+	O	L	40
Anemone apennina	Ranunculaceae	B+, B—	O	O	133
Anemone canadensis	Ranunculaceae	B—, M	Aq	S	120
Anemone nemorosa	Ranunculaceae	B+, B—	O	Fl, L, R	40
Anemone pulsatilla	Ranunculaceae	B+, B—, M, Y, P	O	O	6, 70, 133, 168
Anemone quinquefolia	Ranunculaceae	M	Aq	E	42
Anemone rupicola	Ranunculaceae	B+, B—	O	O	133
Anemopsis californica	Saururaceae	B+, M	EJ	E	5, 71
Angelica arguta	Umbelliferae	B+, B—	E	R, S, St	16
Angelica silvestris	Umbelliferae	Ph	O	O	35, 36
Angophora intermedia	Myrtaceae	B+	Aq	Fl, L	4
Annona cherimolia	Annonaceae	B+, B—	O	O	133
Annona purpurea	Annonaceae	M	Ale	L	119
Antennaria margaritacea (*Anaphalis margaritacea*)	Compositae	B+	Aq, Ale, E	E	120, 10, 42
Antennaria plantaginifolia	Compositae	B—	E	O	16
Antennaria rosea	Compositae	B+	EJ	E	71
Anthemis cotula	Compositae	B+, M	Aq, Ac, EJ, E	E	5, 71, 16 123
Anthemis nobilis	Compositae	B+	Ale	Fl	41
Anthemis tinctoria	Compositae	B+	Ac	O	123
Antigonon leptopus	Polygonaceae	B+, Y	—	L	124
Antirrhinum majus	Scrophulariaceae	M	Ale	Fl	120
Apios americana	Leguminosae	B+	Ac, Ale, B, E	R	10, 119
Apium graveolens	Umbelliferae	B+, B—	Al, Aq	petiole, L, R	112, 171, 42
Aplopappus cooperi	Compositae	B+, M	EJ	E	5, 71
Aplopappus linearifolium	Compositae	B+, M	EJ	E	5, 71
Aplopappus parishii	Compositae	B+, M	EJ	E	5, 71
Aplopappus venetus	Compositae	M	Ale	L	119
Apocynum androsaemifolium	Apocynaceae	B+, B—, M	Ale, Aq, Ac, E, B, +, S	L, St, Fr	10, 16, 41 113
Apocynum cannabinum	Apocynaceae	B+,B—, M	Aq, S	Fl, L, R	16, 41
Aquilegia australis	Ranunculaceae	Y	—	L	124
Aquilegia canadensis	Ranunculaceae	M	Aq	L, St	42
Arabidopsis thaliana	Cruciferae	B+	O	O	40
Aralia nudicaulis	Araliaceae	B+	Al	O	10
Aralia racemosa	Araliaceae	B+	Ale	O	123
Arbutus canariensis	Ericaceae	B+, B—	O	O	133
Arbutus menziesii	Ericaceae	B+, B—, M	Ale, Alm, Aq	Fl, L	65
Arctium lappa	Compositae	B+, B—	O	O	133, 40 168
Arctium minus	Compositae	B+, B—	Aq, E	L, R, Fr	20, 21, 40, 55, 16
Arctium nemorosum	Compositae	B+, B—	O	O	40
Arctostaphylos drupacea	Ericaceae	M	EJ	O	5
Arctostaphylos patula	Ericaceae	M	EJ	O	5
Arctostaphylos uva-ursi	Ericaceae	B+, B—	O	O	40, 171
Arctotis stoechadifolia	Compositae	B+	O	O	133
Argemone mexicana	Papaveraceae	Y	Aq, —	Fl, L	138
Aristolochia clematitis	Aristolochiaceae	B+, M	Aq	L	133, 120
Aristolochia fimbriata	Aristolochiaceae	B+	O	O	133
Aronia arbutifolia	Rosaceae	M	Ale	L, St, Fr	119

Plant Name	Family	Activity	Type of Extract	Plant Part Tested	Ref's
Artabotrys odoratissimus	Annonaceae	B+, B—	O	O	133
Artemisia biennis	Compositae	M	EJ	O	5
Artemisia californica	Compositae	B+	EJ	E	71
Artemisia douglasiana	Compositae	B+	EJ	E	71
Artemisia ludoviciana	Compositae	B+	EJ	E	71
Artemisia rothrockii	Compositae	B+	EJ	E	71
Asarum canadense	Aristolochiaceae	B+	O	L, St	18, 171, 133
Asarum europaeum	Aristolochiaceae	B+	O	E	133
Asclepias incarnata	Asclepiadaceae	B+, B—	E, S	Fl, L, St	16
Asclepias mexicana	Asclepiadaceae	B+, B—	S	L, St, R	16
Asclepias tuberosa	Asclepiadaceae	M	Aq	St	41
Asclepias verticillata	Asclepiadaceae	B+, B—	E	O	16
Asparagus officinalis	Liliaceae	B+, B—	O	O	40
Asparagus spengeri	Liliaceae	Y	Aq	St	124
Asperugo procumbens	Boraginaceae	B+	O	L	171
Asperula odorata	Rubiaceae	B—	O	L, R	40
Aspidium braunii (*Polystichum braunii*)	Polypodiaceae	B+	Ac	O	123
Astartea fasciculata	Myrtaceae	B+	Aq	Fl, L	4
Aster canescens	Compositae	M	EJ	O	5
Aster chilensis	Compositae	M	Aq	Fl	41
Aster divaricatus	Compositae	B+, B—, M	+, —, Alc, Aq	E, Fl, L, St	113, 42
Aster foliaceus	Compositae	B—	B	O	10
Aster nemoralis	Compositae	B+	Alc	O	123
Aster novae-angliae	Compositae	B+	E	O	16
Astragalus douglasii	Leguminosae	M	EJ	O	5
Atriplex arenaria	Chenopodiaceae	Y	—	L, St	124
Atriplex phyllostegia	Chenopodiaceae	M	EJ	O	5
Atriplex semibaccata	Chenopodiaceae	F	EJ	O	5
Aucuba japonica	Cornaceae	B+, B—, M	Aq, Ac	L, R	42, 168 169, 132
Avena sativa	Gramineae	M	Aq	R	41
Azara arborea	Flacourtiaceae	B+, B—	O	O	133
Azara gilliesii	Flacourtiaceae	B+, B—	O	O	133
Azara integrifolia	Flacourtiaceae	B+, B—	O	O	133
Azara microphylla	Flacourtiaceae	B+, B—	O	O	133
Azolla caroliniana	Salviniaceae	Y	Aq	E	138

B

Plant Name	Family	Activity	Type of Extract	Plant Part Tested	Ref's
Baccharis glutinosa	Compositae	B+, F, M	Alc, EJ	O	5, 119
Baccharis halimifolia	Compositae	Y	Aq, —	L	124
Baccharis viminea	Compositae	B+	EJ	E	71
Bahia dissecta	Compositae	B+, M	EJ	E	71, 5
Baileya pauciradiata	Compositae	M	EJ	O	5
Ballota nigra	Labiatae	M	Aq	Fl, L, St	41
Baptisia australis	Leguminosae	B+, B—, M	Aq	Fr, L, S, St	41
Baptisia tinctoria	Leguminosae	B+, M	Alc, Aq	L	120
Barbarea vulgaris	Cruciferae	M	Aq, Alc	L, St, Fl	42, 120
Bauhinia hawkesiana	Leguminosae	B+	O	E	133
Begonia fuchsioides	Begoniaceae	B+	Aq	Fl, L	42
Begonia heracleifolia	Begoniaceae	B+, B—	Aq	Fl, L	42
Begonia semperflorens	Begoniaceae	B+, B—	Aq	Fl, L	42
Beloperone californica	Acanthaceae	B+	EJ	E	71
Berberis asiatica	Berberidaceae	B+, B—	O	B	55
Berberis julianae	Berberidaceae	B+	Alc	L	119
Berberis thunbergii	Berberidaceae	B—, Y	Aq, —	L	138
Bergenia crassifolia	Saxifragaceae	B+, M	Aq	L	41
Berteroa incana	Cruciferae	M, B+	Aq	E, Fl, L, St	42, 120
Beta vulgaris	Chenopodiaceae	F, Ph, V	Aq	R	35, 36, 45

Plant Name	Family	Activity	Type of Extract	Plant Part Tested	Ref's
Betula davurica	Betulaceae	M	Ale	L	41
Betula papyrifera	Betulaceae	B+	Ac, Ale	O	123
Betula populifolia	Betulaceae	B+, M	Ac, Ale, Aq, E	S, St	42, 123
Bidens bipinnata	Compositae	B+, Y	Aq, +, —	L, St	138
Bidens cernua	Compositae	B+	Al Ac, E	O	10
Bidens frondosa	Compositae	B+, B—	EJ, Ac, E, S	E, L, R, St	71, 10, 16
Bidens laevis	Compositae	M	EJ	O	5
Bidens pilosa	Compositae	B+	EJ	E	71
Bignonia radicans	Bignoniaceae	B+	—	L	124
Biscutella californica (*Dithyrea californica*)	Cruciferae	M	EJ	O	5
Bocconia cordata (*Macleaya cordata*)	Papaveraceae	B+, M	Ale, Aq	Fl, L, St	120
Boehmeria argentea	Urticaceae	B+, M	Aq	L, St	120
Brasenia schreberi	Nymphaceae	B+, Y	Ac, Ale, Aq, —	L	123, 138
Brassica arvensis	Cruciferae	F, M	EJ	O	5
Brassica japonica	Cruciferae	M	Aq	S	42
Brassica oleracea	Cruciferae	B+, B—, M, F, Ph	Aq, SD, EJ	L, T, S, Sl	35, 36, 38, 40, 42, 45, 66, 118, 133, 139
Brassica rapa	Cruciferae	B+, B—, M, F	Ale, EJ, Aq, SD	T, S	112, 153, 42, 45
Brickellia californica	Compositae	B+, B—	EJ	E	71
Bromus inermis	Gramineae	B+, M	Aq	Fl, L, R, St	41
Bromus rubens	Gramineae	M	EJ	O	5
Bryophyllum pinnatum	Crassulaceae	B+	Aq	L, St	120
Bunias orientalis	Cruciferae	B+	O	Fl, L, R	40
Butia capitata	Palmaceae	Y	—	L	124
Buxus microphylla	Buxaceae	B+, Y	Aq, —	L, St	138
Buxus sempervirens	Buxaceae	M, F, B+, B—	Ale, Aq	L, St	42, 120, 167

C

Plant Name	Family	Activity	Type of Extract	Plant Part Tested	Ref's
Cakile maritima	Cruciferae	B—	O	O	40
Calceolaria herbeohybrida	Scrophulariaceae	B+, M	Ale, Aq	Fl, L, R, S	41, 42
Callicarpa americana	Verbenaceae	B+, B—	Ale, —	L, Fr	119, 124
Callicarpa dichotoma	Verbenaceae	M	Aq	L, St	41
Callistemon citrinus	Myrtaceae	B+	Aq	Fl, L	4
Callistemon linearis	Myrtaceae	B+, B—, M	Ale	Fr	41
Callistemon pallidus	Myrtaceae	B+	Aq	Fl, L	4
Callistemon palludosus	Myrtaceae	B+	Aq	Fl	4
Callistemon phoeniceus	Myrtaceae	B+	Aq	Fl	4
Callistemon salignus	Myrtaceae	B+	Aq	Fl	4
Callistemon viminalis	Myrtaceae	B+	Aq	Fl, L	4
Callistemon violaceae	Myrtaceae	B+	Aq	Fl, Fr, L	4
Calluna vulgaris	Ericaceae	B+, B—	O	L	171
Calyptridium monandrum	Portulacaceae	F	EJ	O	5
Campanula rotundifolia	Campanulaceae	B+, B—, M	O	Fl, L	40
Camptotheca acuminata	Nyssaceae	M	Ale	L	41
Cananga odorata	Annonaceae	B+, B—	Aq	L	42
Candidea stenostegia	Compositae	B+	O	O	133
Canna flaccida	Cannaceae	M	Aq	L, St	42
Cannabis indica	Moraceae	B+	O	O	110
Cannabis sativa	Moraceae	B+, M	Ale, Aq	Fl, L, St	41
Capraria biflora	Scrophulariaceae	B+, B—, M, Y	Al	R	48, 49, 51

Plant Name	Family	Activity	Type of Extract	Plant Part Tested	Ref's
Capsicum frutescens	Solanaceae	B+, F, M, P	Aq, EJ	E, L, Sl	66, 160, 38, 41
Caragana frutex	Leguminosae	B+	Aq	L	42
Cargana microphylla	Leguminosae	B—, M	Aq	L, S	120
Cardiospermum halicacabum	Sapindaceae	B+, B—	O	O	133
Carex panicea	Cyperaceae	B+	O	O	40
Carex pilulifera	Cyperaceae	B+, B—	O	O	40
Carex vesicaria	Cyperaceae	B—	O	O	40
Carica papaya	Caricaceae	B+, M	Aq	R, L	41, 42
Carphephorus corymbosus	Compositae	B—, Y	Aq, —	Fl, L	138
Carpinus betulus	Betulaceae	B+	O	L	171
Carthamus tinctorius	Compositae	B—	EJ	Sl	66
Carya illinoensis (*Hicoria pecan*)	Juglandaceae	Y, M	+, —, Alc	L	124, 119
Caryopteris incana	Verbenaceae	B+	Alc, Aq	L, St	41
Cassia absus	Leguminosae	B+	O	S	60, 155
Cassia alata	Leguminosae	B+	Alc	Fl, L	119
Cassia angustifolia	Leguminosae	B+	Aq	L	1
Cassia fistula	Leguminosae	B+, B—	Al	Fr, S	135
Cassia obovata	Leguminosae	B+, B—	Al	L	136
Cassia reticulata	Leguminosae	B+, M	Al, Aq	L	1, 2, 147, 174
Cassia tora	Leguminosae	B+, F	Al	S	136
Castanea sativa	Fagaceae	B+, B—, M	Aq	Fr	42
Castenopsis sempervirens	Fagaceae	B+, B—, M	EJ	E	5, 71
Castilleja cinerea	Scrophulariaceae	M	EJ	O	5
Castilleja foliolosa	Scrophulariaceae	B+, M	EJ	E	5, 71
Castilleja miniata	Scrophulariaceae	B+	EJ	E	71
Castilleja pinctorum	Scrophulariaceae	B+	EJ	E	71
Casuarina decaisneana	Casuarinaceae	B+	Aq	L	4
Casuarina equisetifolia	Casuarinaceae	Y	—	St	138
Catalpa speciosa	Bignoniaceae	B+, F	Alc, Aq	Fr, S	67, 120, 128, 129
Caucalis anthriscus (*Torilis anthriscus*)	Umbelliferae	B+, B—	E	O	16
Caulophyllum thalictroides	Berberidaceae	M	Aq	L, St	42
Ceanothus americanus	Rhamnaceae	B+	Aq	L	41
Ceanothus cordulatus	Rhamnaceae	B+, M	EJ	E	5, 71
Ceanothus crassifolius	Rhamnaceae	M	EJ	O	5
Ceanothus velutinus	Rhamnaceae	B+, B—	+, E	L, St	16
Cecropia guarumo	Moraceae	M	Alc	E	41
Cedrus libani	Pinaceae	M	Alc	L	119
Celastrus scandens	Celastraceae	B+, B—, F	Ac	R	100, 77, 84
Celtis caucasica	Ulmaceae	B+	Alc	Fr, L	41
Centaurea americana	Compositae	B+, M	Aq	Fl, L	55
Centaurea jacea	Compositae	B—	S	O	16
Centaurea macrocephala	Compositae	B+	O	O	133
Centaurea maculosa	Compositae	B+, B—	E	L	19
Centaurea nigra	Compositae	B+	Ac, Alc, E	O	123
Centaurea pulchra	Compositae	B+	O	O	133
Centaurea scabiosa	Compositae	B+	O	O	133
Centaurea solstitialis	Compositae	B+, B—	EJ	E	40, 71
Centaurea stenostegia	Compositae	B+	O	O	133
Centella erecta	Umbelliferae	B+	Aq	L, St	138
Ceratiola ericoides	Empetraceae	B+, Y	—	L	124
Ceratostigma plumbaginoides	Plumbaginaceae	B+, B—	O	L	171
Cercis canadensis	Leguminosae	B+	Aq	S	120
Cercis siliquastrum	Leguminosae	B+, B—	O	L	171
Cercocarpus betuloides	Rosaceae	B+, M	EJ	E	5, 71
Chaenactis glabriuscula	Compositae	B+	EJ	E	71
Chaenomeles lagenaria	Rosaceae	B—	Aq, —	L	138

Plant Name	Family	Activity	Type of Extract	Plant Part Tested	Ref's
Chaerophyllum temulum	Umbelliferae	B+	O	R	40
Chamaecyparis pisifera	Cupressaceae	B+, M	Ale, Aq	L, St	·41
Chamaelaucium axillare	Myrtaceae	B+	Aq	Fl	4
Chamaelaucium megalopetalum	Myrtaceae	B+	Aq	Fl	4
Chamaelaucium uncinatum	Myrtaceae	B+	Aq	Fl	4
Cheilanthes covillei	Polypodiaceae	F, M	EJ	O	5
Cheiranthus allionii	Cruciferae	B+, B—	O	S	133
Cheiranthus cheiri	Cruciferae	B+, B—, F	EJ	S, Sl, L	46, 66, 133, 171
Chelidonium majus	Papaveraceae	B+	Ale	R	120
Chelone glabra	Scrophulariaceae	B+	Aq	O	10
Chenopodium album	Chenopodiaceae	F, B+, B—	Al, E, S	L	157, 16
Chenopodium leptophyllum	Chenopodiaceae	M	EJ	O	5
Chilopsis linearis	Bignoniaceae	B+, B—, M	EJ	E	5, 71
Chimaphila maculata	Pyrolaceae	B+	Ale	E	119
Chimaphila umbellata	Pyrolaceae	B+, B—	Ac, Al, B, E	O	10
Chondrodendron tomentosum	Menispermaceae	B+, B—	Ac	R	104, 77, 83
Chorizanthe brevicornu	Polygonaceae	B+, M	EJ	E	71, 5
Chrysanthemum cinerariaefolium	Compositae	M	Aq	Fl	120
Chrysanthemum frutescens	Compositae	M	Ale, Aq	R	41
Chrysanthemum macrophyllum	Compositae	B+	O	L	171
Chrysanthemum maximum	Compositae	B+, M	Ale, Aq	Fl	42
Chrysanthemum morifolium	Compositae	B+, M	Ale, Aq	R, L, St	42, 41
Chrysanthemum parthenium	Compositae	B+, M B—	Aq	E	55
Chrysanthemum segetum	Compositae	B+, M	Ale, Aq	Fl, L, St	120
Chrysanthemum vulgare	Compositae	B+, B—	O	O	40
Chrysobalanus oblongifolia	Rosaceae	B—	Aq	L	138
Chrysopsis graminifolia	Compositae	Y	—	Fl, L	138
Chrysopsis mariana	Compositae	B+, B—	+, —, E, S,	O	16
Chrysothamnus nauseosus	Compositae	M	EJ	O	5
Cichorium intybus	Compositae	B+, F, Y	Al, +	St, buds	112, 113, 157
Cipadessa baccifera	Meliaceae	B+	Ale	Fl, Fr, L	41
Circaea quadrisulcata	Onagraceae	B+	Ale	E	119
Cirsium arvense	Compositae	B+, B—	Al, Ac, B, E,	O	40, 10, 77
Cirsium lanceolatum	Compositae	M	Aq	L	55
Cirsium muticum	Compositae	B+	—	O	113
Cirsium oleraceum	Compositae	B+	O	O	40
Cirsium vulgare	Compositae	B+	Ac, Al, E	O	10
Citrullus colocynthis	Curcurbitaceae	B+, B—	Al	Fr	137
Citrus paradisi	Rutaceae	B+, B—, M, Y	Ale, Aq, +	L, R	42, 138
Clarkia elegans	Onagraceae	B+	Aq	Fl, L, R, St	120
Clematis armandii	Ranunculaceae	B+, B—	O	O	133
Clematis baldwinii	Ranunculaceae	Y	+, —	Fl, L	138
Clematis dioscoreifolia	Ranunculaceae	B+, B—, Y	Aq, +, —	O	69, 124
Clematis fremontii	Ranunculaceae	B+, B—	O	O	133
Clematis heracleaefolia	Ranunculaceae	B+, B—	O	O	133
Clematis pauciflora	Ranunculaceae	B+, B—	EJ	E	71
Clematis recta	Ranunculaceae	B+, B—	Ale	S, L	119, 133
Clematis stans	Ranunculaceae	B+, B—	O	O	133
Clematis texensis	Ranunculaceae	B+, B—	O	O	133
Clematis virginiana	Ranunculaceae	F	Al	O	157
Clematis vitalba	Ranunculaceae	B+, B—	EJ	L	171, 170
Clerodendrum indicum	Verbenaceae	Y	—	L	138

Plant Name	Family	Activity	Type of Extract	Plant Part Tested	Ref's
Clinopodium coccineum	Labiatae	Y	Aq, —	L, St	124
Clytostoma callistegioides	Bignoniaceae	B+, Y	+, Aq	L	124
Cneorum tricoccon	Cneoraceae	B+, M	Alc, Aq	L, R, St	42
Cnicus benidictus	Compositae	B+, B—, M	EJ	E	5, 71
Coccolobis uvifera	Polygonaceae	B+, M	Aq	L, St	42
Codiaeum variegatum	Euphorbiaceae	M	Aq	L, St	120
Coldenia plicata	Boraginaceae	B+	EJ	E	71
Coleus blumei	Labiatae	B+, M	Aq	L, R, St, E	55, 133
Coleus thyrsoideus	Labiatae	B+	O	E	133
Collinsia parryi	Scrophulariaceae	B+	EJ	E	71
Collinsonia canadensis	Labiatae	Y	—	Fl, L	138
Comptonia peregrina (*Myrica asplenifolia*)	Myricaceae	B+, B—, M	Alc, Aq	Fl, L, St	42, 55
Conium maculatum	Umbelliferae	B+	O	L	171
Conradina canescens	Labiatae	Y	—	L, St	138
Convallaria majalis	Liliaceae	B+	O	Fl, R	40
Convolvulus occidentalis	Convolvulaceae	B+	EJ	E	71
Coptis chinensis	Ranunculaceae	B+, B—	Alc	R	23
Corallorhiza trifida	Orchidaceae	B+	Ac	O	123
Cordylanthus filifolius	Scrophulariaceae	M	EJ	O	5
Coreopsis bigelovii	Compositae	B+	EJ	E	71
Coreopsis douglasii	Compositae	B+	EJ	E	71
Corethrogyne filaginifolia	Compositae	M	EJ	O	5
Cornus canadensis	Cornaceae	B+	Ac, E	O	10
Cornus florida	Cornaceae	B+, Y, B—, M	+, —, Aq, Alc, Ac	L, R, St, Fl	124, 77, 138, 119
Cornus nuttallii	Cornaceae	B+, B—	+, —	L, St	16
Cornus stolonifera	Cornaceae	B+, B—	+	O	16
Cornus stricta	Cornaceae	B+	+, —	Fr, L	138
Cornus walteri	Cornaceae	M	Alc	L	119
Coronilla varia	Leguminosae	M	Aq	L, St	41
Correa pulchella	Rutaceae	B+	Aq	St	120
Corydalis bulbosa	Papaveraceae	B+	O	O	133
Corydalis cava	Papaveraceae	B+, B—	O	Fl, R	40
Cotoneaster acuminata	Rosaceae	B+	Aq	Fr	120
Cotinus coggygria	Anacardiaceae	B+, B—	Alc, Aq	L, St, Fl	42, 120
Cotula coronopifolia	Compositae	F	EJ	O	5
Crassula arborescens	Crassulaceae	B+, B—, M	Aq	L, R, St	42
Crataegus aestivalis	Rosaceae	B—	Aq	L	138
Crataegus monogyna	Rosaceae	B+	Aq	St	120
Crataegus oxyacantha	Rosaceae	B+	Aq	Fr, L	120
Crepis capillaris	Compositae	B+	O	O	133
Crepis incana	Compositae	B+	O	O	133
Crepis taraxicifolia	Compositae	B+, B—	Aq	R, St, Fl	68, 133
Crotalaria retzii	Leguminosae	B+	+, —	S, Fr	124
Croton coccineus (*Mallotus philippinensis*)	Euphorbiaceae	B+, B—	Ac	O	77
Croton sellowii	Euphorbiaceae	B+, B—, M	Ac	R	52
Cryptomeria japonica	Taxodiaceae	B+, M	Alc, Aq	L, St	41
Cryptotaenia canadensis (*Deringa canadensis*)	Umbelliferae	B+, B—	+, —, Alc	Fr, R, St	16, 41, 119
Cucumis melo	Cucurbitaceae	F	Al	O	157
Cucumis sativus	Cucurbitaceae	B+	Aq	Fr	112
Cucurbita foetidissima	Cucurbitaceae	B+	Alc	L	119
Cucurbita pepo	Cucurbitaceae	B+, M	Aq	Fr	156
Cunninghamia lanceolata	Taxodiaceae	B—	Aq	L	138
Curcuma longa	Zingiberaceae	B+	O	Rh	142
Cyclamen persicum	Primulaceae	B+	Aq	L	120
Cynara carduculus	Compositae	B+, B—	EJ	Sl	66
Cynara scolymus	Compositae	B+, B—	EJ	Sl	66
Cyrilla racemiflora	Cyrillaceae	Y	Aq, —	L	138

D

Plant Name	Family	Activity	Type of Extract	Plant Part Tested	Ref's
Dahlia variabilis	Compositae	B+, M	Aq	Fl	55
Dalea californica	Leguminosae	B+, M	EJ	E	5, 71
Dalea emoryi	Leguminosae	M	EJ	O	5
Darwinia citriodora	Myrtaceae	B+	Aq	Fl, L	4
Dasylirion berlandieri	Liliaceae	B+	Alc	Fl, L	41
Datisca cannabina	Datiscaceae	B+	O	O	133
Datisca glomerata	Datiscaceae	B+	EJ	E	71
Datura cornigera	Solanaceae	B+	Alc	Fl	120
Datura meteloides	Solanaceae	M	EJ	O	5
Datura stramonium	Solanaceae	B+, B−	Ac, Alc, Ag, E	L, S, St	16, 123
Daucus carota	Umbelliferae	B+, B−, F, Ph	Al, Aq	R	35, 36, 40, 107,112
Decodon verticillatus	Lythraceae	Y	Aq, —	L, St	124
Dendromecon rigida	Papaveraceae	B+	EJ	E	71
Dendropanax japonicum	Araliaceae	B+	O	O	133
Dennstaedia punctilobula	Polypodiaceae	B+	Ac	O	123
Deringa canadensis (*Cryptotaenia canadensis*)	Umbelliferae	B+, B−	+, −	O	16
Desmodium canadense (*Meibomia canadensis*)	Leguminosae	B+, B−	+, −, E, S	O	16
Desmodium rigidum (*Meibomia rigidum*)	Leguminosae	B+, B−	+, S	O	16
Diervilla lonicera	Caprifoliaceae	B+	Al, Aq, E	O	10
Dion spinulosum	Cycadaceae	B−	Aq	L	42
Dioscorea bulbifera	Dioscoreaceae	Y	—	L, T	124
Diospyros ebenaster	Ebenaceae	M	Alc	L, Fr	119
Diospyros virginiana	Ebenaceae	B−	+	L	124
Dipelta floribunda	Caprifoliaceae	M	Alc	L	41
Diplotaxis muralis	Cruciferae	B+	E	O	16
Dithyrea californica (*Biscutella californica*)	Cruciferae	M	EJ	O	5
Dovantha unguis-cati	Bignoniaceae	B+	Alc	L	41
Drosera tracyi	Droseraceae	B−, Y	—	L, St	124
Dryopteris arguta	Polypodiaceae	B+, M	EJ	E	71, 5
Dryopteris filix-mas	Polypodiaceae	B+	O	O	40

E

Plant Name	Family	Activity	Type of Extract	Plant Part Tested	Ref's
Echeveria lanceolata	Crassulaceae	M	EJ	O	5
Eichornia crassipes	Pontederiaceae	B+, B−, Y	+, −	L, St, R	124
Elephantopus tomentosus	Compositae	B+, B−	+	Fl, L	138
Empetrum atropurpureum	Empetraceae	B+	Al,E	O	10
Empetrum nigrum	Empetraceae	B+, B−	Ac, Al, E	L	171, 10
Ephedra californica	Gnetaceae	B+ M	EJ	E	5, 71
Epidendrum sp.	Orchidaceae	B+ M	Alc	R	41
Epifagus virginiana	Orobanchaceae	Y	—	Fl, L	138
Epilobium angustifolium	Onagraceae	B−	Al, Aq	O	157
Epilobium californicum	Onagraceae	B+	EJ	E	71
Epilobium coloratum	Onagraceae	B+, B−, M	Alc, Aq	Fr, L, R, St	41
Epilobium montanum	Onagraceae	B−	O	O	40
Epimedium alpinum	Berberidaceae	B+	O	L	171
Epimedium peraldianum	Berberidaceae	B+	O	O	133
Epimedium pinnatum	Berberidaceae	B+	O	O	133
Epimedium youngianum	Berberidaceae	B+	O	O	133
Episcia cupreata	Gesneriaceae	M	Aq	L, St	42
Equisetum arvense	Equisetaceae	B+, M	EJ	E	124
Equisetum fluviatile	Equisetaceae	B+, B−	O	O	40
Eragrostis mexicana	Gramineae	M	EJ	O	5
Erechtites hieracifolia	Compositae	B+	Ac, E	O	10
Erigeron canadensis	Compositae	B+, B−, M	Ac, Alc, E, Aq	Fl, L	123, 55, 16

Plant Name	Family	Activity	Type of Extract	Plant Part Tested	Ref's
Erigeron divergens	Compositae	B+, M	EJ	E	5, 71
Erigeron philadelphicus	Compositae	B+, B−	Ac	O	10
Erigeron pulchellus	Compositae	M	Aq	E	42
Erigeron vernus	Compositae	B−	Aq	L, St	138
Eriobotrya japonica	Rosaceae	B+, M	Aq	L, R, St	42
Eriodictyon californicum	Hydrophyllaceae	B+, B−, M	Ac, Alc	L, St	77, 150
Eriodictyon crassifolium	Hydrophyllaceae	B+	EJ	E	71
Eriodictyon glutinosum	Hydrophyllaceae	B+, M	Alc	L	55
Eriodictyon parryi	Hydrophyllaceae	B+	EJ	E	71
Eriodictyon trichocalyx	Hydrophyllaceae	B+	EJ	E	71
Eriogonum angulosum	Polygonaceae	B+, M	EJ	E	5, 71
Eriogonum cinereum	Polygonaceae	B+, M	EJ	E	5, 71
Eriogonum elongatum	Polygonaceae	B+, M	EJ	E	5, 71
Eriogonum fasciculatum	Polygonaceae	B+	EJ	E	71
Eriogonum heermanii	Polygonaceae	B+, M	EJ	E	5, 71
Eriogonum molestum	Polygonaceae	B+	EJ	E	71
Eriogonum parishii	Polygonaceae	B+, M	EJ	E	5, 71
Eriogonum parvifolium	Polygonaceae	B+, M	EJ	E	5, 71
Eriogonum reniforme	Polygonaceae	M	EJ	O	5
Eriogonum umbellatum	Polygonaceae	B+	EJ	E	71
Eriogonum wrightii	Polygonaceae	B+, M	EJ	E	5, 71
Eriophyllum confertiflorum	Compositae	B+, M	EJ	E	5, 71
Erodium texanum	Geraniaceae	B+	EJ	E	71
Eryngium prostratum	Umbelliferae	B+	—	Fl, L	138
Erysimum asperum	Cruciferae	B+, B−, M	EJ	E	5, 71
Erysimum perofskianum	Cruciferae	B+, B−	O	S	133
Eucalyptus alba	Myrtaceae	M	Alc	Fr, L	41
Eucalyptus fasciculata	Myrtaceae	B+	Aq	Fl	4
Eucalyptus globulus	Myrtaceae	M	Alc	L	55
Eucalyptus lehmannii	Myrtaceae	B+	Aq	Fl, Fr, L	4
Eucalyptus leucoxylon	Myrtaceae	B+	Aq	Fl, Fr	4
Eucalyptus megacarpa	Myrtaceae	B+	Aq	Fl	4
Eucalyptus niphophila	Myrtaceae	M	Alc	L	119
Eucalyptus sepulcralis	Myrtaceae	B+	Aq	Fl, L	4
Eucalyptus staigeriana	Myrtaceae	B+	Alc	Fr, L	119
Eucomis comosa	Liliaceae	B+, B−	Alc	E	41
Eugenia atropunctata	Myrtaceae	B+	Aq	L, R, St	119
Euonymus europaeus	Celastraceae	M	Alc	S	41
Eupatorium altissimum	Compositae	B+, B−	E	Fl, L, St.	16
Eupatorium aromaticum	Compositae	B+	Aq, —	L	138
Eupatorium cannabinum	Compositae	B+, B−	O	O	40
Eupatorium capillifolium	Compositae	Y	—	L, St	124
Eupatorium maculatum	Compositae	B+	E	O	10
Eupatorium perfoliatum	Compositae	Y, B+, B−, M	—, Aq, Alc, E, Ac	L, St	124, 113, 10, 16, 42
Eupatorium purpureum	Compositae	B+, B−	S	L, R	16, 138
Eupatorium rugosum	Compositae	B+	Aq	L, S, St	41
Eupatorium urticaefolium	Compositae	B+, B−	+, E	O	16
Euphorbia albomarginata	Euphorbiaceae	B+	EJ	E	71
Euphorbia corollata (*Tithymalopsis corollata*)	Euphorbiaceae	B+, B−	E, S	L, St	16
Euphorbia maculata	Euphorbiaceae	B+	EJ	E	71
Euphorbia palmeri	Euphorbiaceae	M	EJ	O	5
Euphorbia pulcherrima	Euphorbiaceae	Y, B+	+, —, Aq	L, St	124, 120
Euphorbia vermiculata	Euphorbiaceae	B+	Ac	O	10
Euphoria heterophylla	Sapindaceae	M	Aq	Fl, L	55
Euphoria variegata	Sapindaceae	M	Aq	Fl, L	55
Eustoma silenifolium	Gentianaceae	B+, B−	EJ	E	71
Evodia hupehensis	Rutaceae	M	Alc	L, Fr	119, 41
Eysenhardtia amorphoides	Leguminosae	B+, B−	S	O	58

F

Plant Name	Family	Activity	Type of Extract	Plant Part Tested	Ref's
Fagopyrum sagittatum	Polygonaceae	M	Aq	E	42
Fagopyrum tataricum	Polygonaceae	B+, B–	O	O	40
Feijoa sellowiana	Myrtaceae	B+, M, Y	Aq, —	L	42, 138
Festuca gigantea	Gramineae	B+	O	L	172
Festuca glauca	Gramineae	B+	O	L	172
Festuca ovina	Gramineae	B+	O	L	172
Ficus mysorensis	Moraceae	B+	Alc	L	41
Firmiana platanifolia	Sterculiaceae	Y	—	L	124
Flacourtia cataphracta	Flacourtiaceae	B–	O	O	133
Flacourtia ramoutchi	Flacourtiaceae	B+, B–	O	O	133
Flacourtia rukam	Flacourtiaceae	B+	Alc	Fl, L	119
Forsythia suspensa	Oleaceae	B+, M	Alc, Aq	Fl, L, St	42
Fortunearia sinensis	Hamamelidaceae	M	Alc	L	119
Fouquieria peninsularis	Fouquieriaceae	M	Alc	B	41
Fragaria vesca	Rosaceae	B+, B–	Aq	L, R	119, 171
Franseria ambrosioides	Compositae	B+	Alc	E	119
Franseria bipinnatifida	Compositae	B+	EJ	E	71
Fraxinus dipetala	Oleaceae	M	EJ	O	5
Fraxinus excelsior	Oleaceae	M	Aq	L	120
Fritillaria meleagris	Liliaceae	B–	O	O	40
Fuchsia speciosa	Onagraceae	B+	Aq	Fl, R, St	120
Funastrum hirtellum (*Philibertia hirtella*)	Asclepiadaceae	M	EJ	O	5

G

Plant Name	Family	Activity	Type of Extract	Plant Part Tested	Ref's
Gaillardia lanceolata	Compositae	Y	Aq, —	Fl, L	138
Gaillardia pulchella	Compositae	B+	Aq	L	120
Galeopsis tetrahit	Labiatae	B–	O	O	40
Galium angustifolium	Rubiaceae	B+	EJ	E	71
Garcinia morella	Guttiferae	B+, B–	O	S	131, 143, 144
Garcinia spicata	Guttiferae	B+	Alc	Fr, L	119
Gasteria maculata	Liliaceae	M	Aq	R	42
Gaura biennis	Onagraceae	B+	E, S	L, St	16
Gaylussacia baccata	Ericaceae	B+	Ac, Alc	O	123
Genista pilosa	Leguminosae	B–	O	Fl, R	40
Genista tinctoria	Leguminosae	B+, M	Alc, Aq	Fl, L, St	41
Gentiana lutea	Gentianaceae	B+	O	R	55
Geraea canescens (*Encelia eriocephala*)	Compositae	M	EJ	L, St	5
Geranium carolinianum	Geraniaceae	Y	Aq, —	L, St	138
Geranium palustre	Geraniaceae	B+, B–	Aq	L	43
Geranium phaeum	Geraniaceae	B+, B–	Aq	L	43
Geranium platypetalum	Geraniaceae	B+, B–	Aq	L	43
Geranium pratense	Geraniaceae	B–	Aq	L	43
Geranium richardsonii	Geraniaceae	B+	EJ	E	71
Geranium sanguineum	Geraniaceae	B+, B–	Aq	L	43
Geum chiloense	Rosaceae	B+, B–	EJ	Sl	66
Geum macrophyllum	Rosaceae	B+	Ac	O	123
Geum rivale	Rosaceae	B–	O	L, R	40
Geum urbanum	Rosaceae	B–	O	O	40
Geum vernum	Rosaceae	B+	Ac	E	89, 98
Gilia achilleafolia	Polemoniaceae	M	EJ	O	5
Gilia dianthoides	Polemoniaceae	M	EJ	O	5
Gilia gilioides	Polemoniaceae	F	EJ	O	5
Gilia lutea	Polemoniaceae	M	EJ	O	5
Gilia parryae	Polemoniaceae	M	EJ	O	5
Gilia squarrosa (*Navarretia squarrosa*)	Polemoniaceae	B+, B–	E	O	16
Ginkgo biloba	Ginkgoaceae	Y	—	L	124
Glyceria striata	Gramineae	B+	Alc	O	123
Glycyrrhiza glabra	Leguminosae	M	Alc	E	41
Gnaphalium decurrens	Compositae	B+, B–, M	Alc, Aq	Fl, L, R, St	41

Plant Name	Family	Activity	Type of Extract	Plant Part Tested	Ref's
Gnaphalium macounii	Compositae	B+	Ac, Al, E	O	10
Gnaphalium obtusifolium	Compositae	B+, M	Alc, Aq	Fl, L, St	42
Godetia epilobioides	Onagraceae	B+	EJ	E	71
Godetia gilobioides	Onagraceae	B+	EJ	E	71
Godetia grandiflora	Onagraceae	B+	Aq	Fl, R	119
Gondalia parryi	Rhamnaceae	M	EJ	O	5
Grevillea bipinnatifida	Proteaceae	B+	Aq	L	4
Grevillea dallaceana	Proteaceae	B+, B—	Aq	Fl	4
Grevillea robusta	Proteaceae	B+	Aq	E	120
Grindelia nan	Compositae	B+, B—	E	Fl, L, St	16
Grindelia squarrosa	Compositae	B+, B—	Ac, E	Fl, L	16, 77, 82, 102
Gynocardia odorata	Flacourtiaceae	B+, B—	O	O	133
H					
Habenaria psycodes	Orchidaceae	B+	Al, Aq	O	10
Haematoxylon braziletto	Leguminosae	B+, B—	Aq	St	141
Haematoxylon campechianum	Leguminosae	B+, M	Alc	L, Fl, St	105, 106, 117, 119
Hedera canariensis	Araliaceae	B+, Y	—	L	124
Hedychium coronarium	Zingiberaceae	Y	—	L	124
Helenium latifolium	Compositae	Y	—	Fl, L	138
Helenium puberulum	Compositae	B+	EJ	E	71
Helianthemum scoparium	Cistaceae	B+, M	EJ	E	5, 71
Helianthus annuus	Compositae	B+, M	Aq, E, EJ	R, St, L, Fl, E	16, 42, 71
Helianthus decapetalus	Compositae	B+, B—	+, —, E, S	Fl, L, St	16
Helianthus gigantens	Compositae	B—	+	O	16
Helianthus gracilentus	Compositae	B+	EJ	E	71
Helianthus microcephalus	Compositae	B+, B—	E	Fl, L, St	16
Helianthus tuberosus	Compositae	B+, B—	O	R, St	55
Helichrysum coronarium	Compositae	B+	Aq	L, R	120
Heliopsis helianthoides	Compositae	B+, B—	+	O	16
Helleborus niger	Ranunculaceae	B+, B—	O	O	133
Helleborus viridis	Ranunculaceae	B+, B—	O	O	133
Hemerocallis fulva	Liliaceae	B+	O	L	171
Hemichora diandra	Chenopodiaceae	B—	Aq	Fl	4
Hemizonia fasciculata	Compositae	B+, M	EJ	E	5, 71
Hepatica americana	Ranunculaceae	M	Aq	L	42
Herniaria glabra	Illecebraceae	B—	O	O	40
Heteromeles arbutifolia (Photinia arbutifolia)	Rosaceae	M	EJ	O	5
Heuchera americana	Saxifragaceae	B+, M	Aq	L	41
Heuchera rubescens	Saxifragaceae	B+	EJ	E	71
Hibiscus esculentus	Malvaceae	B+	Al	Fr	112
Hibiscus mutabilis	Malvaceae	B+, B—, Y	Aq, +, —	L, S, Fr	124
Hibiscus syriacus	Malvaceae	M	Aq	Fl	41
Hieracium albiflorum	Compositae	B+	EJ	E	71
Hieracium amplexicaule	Compositae	B+	O	O	133
Hieracium aurantiacum	Compositae	B+	E	O	133, 10
Hieracium caespitosum	Compositae	B+	O	Fl	40
Hieracium gymnocephalum	Compositae	B+	O	O	133
Hieracium murorum	Compositae	B+	O	O	133
Hieracium pratense	Compositae	B+, B—	Ac, Al	O	10
Hieracium rupestre	Compositae	B+	O	O	133
Hieracium umbellatum	Compositae	B+	O	O	133
Hippocratea indica (Pristimera indica)	Hippocrateaceae	B+	O	R	9, 140, 152
Hippophaë rhamnoides	Elaeagnaceae	M	Alc	L	41
Hoffmannia ghiesbreghtii	Rubiaceae	B+	Aq	L	120
Holodiscus dumosus	Rosaceae	M	EJ	O	5
Hordeum murinum	Gramineae	B+	O	L	172

Plant Name	Family	Activity	Type of Extract	Plant Part Tested	Ref's
Hormium pyrenaicum	Labiatae	B+, B—	O	L	171
Hosta japonica	Liliaceae	B—	Alc	Fr, S	41
Hottonia palustris	Primulaceae	B+	O	Fl, L	40
Hudsonia ericoides	Cistaceae	B+	Ac, Alc	O	123
Humulus lupulus	Cannabinaceae	B+, B—, M, F	Aq, +, —, Ac, Alc, E, S	Fl, Fr	16, 24, 25, 55, 123, 130, 149
Hydnocarpus anthelminticus	Flacourtiaceae	B+, B—	O	O	133
Hydnocarpus ilicifolia	Flacourtiaceae	B+, B—	O	O	133
Hydnocarpus wightianus	Flacourtiaceae	B+, B—	O	O	133
Hydrangea arborescens	Saxifragaceae	M	Aq	R	120
Hydrangea quercifolia	Saxifragaceae	B+, Y	—	L	124
Hydrangea sp.	Saxifragaceae	B—, M	Alc, E	L, R, St	132
Hydrastis canadensis	Ranunculaceae	B+, M	Aq	R	55
Hydrocotyle umbrellata	Umbelliferae	Y	Aq	L	138
Hydrophyllum virginianum	Hydrophyllaceae	B+, B—	Aq	R, St	42
Hymenocallis americana	Amaryllidaceae	B+, B—, M	Aq	Bu, L, R	42
Hymenocallis macleana	Amaryllidaceae	M	Aq	Bu, L	120
Hymenoclea pentalepis	Compositae	B+, M	Alc	L	119
Hymenoclea salsola	Compositae	B+	EJ	E	71
Hyoscyamus niger	Solanaceae	B+	O	E	55
Hypericum aspalathoides	Hypericaceae	B—	Aq	L, St	138
Hypericum calycinum	Hypericaceae	M	Alc	L	55
Hypericum canadensis	Hypericaceae	B+	Ac, Alc, E	O	123
Hypericum moserianum	Hypericaceae	B+	Alc	Fl	41
Hypericum mutilum	Hypericaceae	B+	E	O	16
Hypericum perforatum	Hypericaceae	B+, B—, M	Ac, Alc, E, Aq	E, Fl, L, R, St	40, 97, 90, 10, 42, 16
Hypericum polyphyllum	Hypericaceae	B+, B—	Alc	Fl	41
Hypericum prolificum	Hypericaceae	B+, M	Alc, Aq	Fl, L	42
Hypericum virginicum	Hypericaceae	B+	Ac, Alc, E	O	123
I					
Iberis sempervirens	Cruciferae	B+, B—	O	S, L	133, 168, 171
Iberis umbellata	Cruciferae	B+, B—	EJ	Sl	66
Ilex coriacea	Aquifoliaceae	Y	Aq, —	L	138
Ilex glabra	Aquifoliaceae	B+	—	L	138
Impatiens balsamina	Balsaminaceae	B+, F, Y, M	E, Aq	Fl, L	116, 55
Impatiens biflora	Balsaminaceae	F, B+, B—	Al, +, E, S	O	157, 16
Impatiens pallida	Balsaminaceae	M	Aq	R	120
Inula helenium	Compositae	B+, B—, M	Al, Aq, E, S	Fl, L, R, St	10, 16, 42
Ipomoea batatas	Convolvulaceae	B+, B—, M, F	Aq, Alm, EJ	E, L, R, St	13, 38
Ipomoea bonariensis	Convolvulaceae	B+	Alc	Fl, T	119
Ipomoea noctiflora (*Calonyction aculeatum*)	Convolvulaceae	B+	EJ	Sl	66
Ipomoea pandurata	Convolvulaceae	B+	+	O	16
Ipomoea purpurea	Convolvulaceae	B+, B—	—	L, St	124
Iresine herbstii	Amaranthaceae	B+, M	Aq	Fl, L, R, St	120
Iris pseudacorus	Iridaceae	B—	O	Fl, L, R	40
Iris sp.	Iridaceae	B+, B—	Ac	Bu	77
Isanthus brochiatus	Labiatae	B+, B—	+, E	O	16
Isnardia sp.	Onagraceae	Y	—	L, St	138
Isomeris arborea	Capparidaceae	B+	EJ	E	71
J					
Juglans californica	Juglandaceae	B+, B—	EJ	E	71

Plant Name	Family	Activity	Type of Extract	Plant Part Tested	Ref's
Juglans cinerea	Juglandaceae	B+, B—, F	Ac, B, E	R	95, 91, 10
Juglans nigra	Juglandaceae	Y	Aq, —	L	124
Juncus stygius	Juncaceae	B+, B—	Alc	O	123
Juniperus communis	Cupressaceae	B+, B—	Ac	Fr	77
Juniperus conferta	Cupressaceae	B+	C, E, PE	Fr	161, 162
Juniperus horizontalis	Cupressaceae	B+	Alc	O	123
Juniperus japonica	Cupressaceae	B+	C, E, PE	Fr	161, 162
Juniperus occidentalis	Cupressaceae	M	EJ	O	5
Juniperus rigida	Cupressaceae	B+	C, E, PE	Fr	161, 162
Juniperus virginiana	Cupressaceae	B+, B—	Alc	L, St	42
Jussiaea californica	Onagraceae	B+, M	EJ	E	5, 71
Jussiaea erecta	Onagraceae	Y	Aq, —	L, St	124
Jussiaea leptocarpa	Onagraceae	B+, Y	+, —	L, St	124
Jussiaea peruviana	Onagraceae	B+, Y	Aq, +, —	L, St	138
		K			
Kalanchoë daigremontiana	Crassulaceae	B+	Alc	Fl	119
Kalmia angustifolia	Ericaceae	B+, B—	Ac, Al, Aq, E	O	10
Kalmia latifolia	Ericaceae	B+, M	Alc, Aq	L	41
Koeleria alpicola	Gramineae	B+	O	L	172
Koeleria pyramidata	Gramineae	B+	O	L	172
Koelreuteria bipinnata	Sapindaceae	B+	Alc	Fl, L	119
Koelreuteria paniculata	Sapindaceae	B+, M	Aq	L, St	42
Kolkwitzia amabilis	Caprifoliaceae	B+	Aq	Fl, S	41
Krameria argenta	Leguminosae	B+, F	Ac	R	103, 77, 80
Krameria grayi	Leguminosae	B+, M	EJ	E	5, 71
Krameria triandra	Leguminosae	B+, F	Ac	R	103, 77, 80
Kuhnistera pinnata	Leguminosae	Y	—	Fl, L	138
		L			
Laburnum anagyroides	Leguminosae	B+	Aq	Fr	42
Lactuca canadensis	Compositae	M	Aq	E	42
Lactuca floridana	Compositae	B+	+	S, St	16
Lactuca plumieri	Compositae	B+	O	O	133
Lactuca scariola	Compositae	B+	EJ	E	71
Lactuca serriola	Compositae	B+	Aq	Fl	41
Lagerstroemia floribunda	Lythraceae	B+	Alc	Fr, L	119
Lagerstroemia indica	Lythraceae	B+	Alc	L	41
Lantana camara	Verbenaceae	B+	Aq	L, R, St	120
Lapsana communis	Compositae	B+	Ac	L, R, Fl	40, 123, 133
Larix europaea	Pinaceae	B+, B—	Alc	S	41
Larrea divaricata	Zygophyllaceae	B+, M	EJ	E	5, 71
Larrea tridentata	Zygophyllaceae	B+, M	Alc	L	119
Lastarriaea chilensis	Polygonaceae	M	EJ	O	5
Lathyrus lactiflorus	Leguminosae	M	EJ	O	5
Lathyrus montanus	Leguminosae	B—	O	Fl	40
Lavandula officinalis	Labiatae	B+	O	L	171
Layia glandulosa	Compositae	B+, M	EJ	E	5, 71
Layia platyglosa	Compositae	B+	EJ	E	71
Lechea intermedia	Cistaceae	B+	Ac, Aq	O	123
Ledum palustre	Ericaceae	B+, B—	O	L	171
Leea hirta	Vitaceae	B+, M	SD	R	59
Lepachys pinnata (*Ratibida pinnata*)	Compositae	B+, B—	E, S	O	16
Lepidium campestre	Cruciferae	M, B—	Aq, S	E, Fl, L, R, St	42, 16
Lepidium densiflorum	Cruciferae	B+	Ac, E	O	10
Lepidium draba	Cruciferae	B+, B—, M	EJ	E	5, 71
Lepidium flavum	Cruciferae	B+, B—, M	EJ	E	5, 71

Plant Name	Family	Activity	Type of Extract	Plant Part Tested	Ref's
Lepidium fremontii	Cruciferae	M	EJ	O	5
Lepidium hyssopifolium	Cruciferae	B+	Aq	L, R, S, St	4
Lepidium virginicum	Cruciferae	B+, B—, Y	E, —, EJ	E, L, Fr	113, 160, 71
Leptilon canadense (*Erigeron canadensis*)	Compositae	B+	E	O	16
Leptospermum laevigatum	Myrtaceae	B+	Aq	L	4
Leptosyne maritima	Compositae	B+	Aq	R	134
Leptotaenia dissecta	Umbelliferae	B+, B—, F	SD	R	14, 16
Leptotaenia multifeda	Umbelliferae	B+, B—	Aq, EA	R, L	127, 125
Lessingia germanorum	Compositae	M	EJ	O	5
Leucothoe acuminata	Ericaceae	B—	Aq, —	L, St	138
Leycesteria formosa	Caprifoliaceae	B+, B—	O	L	171
Liatris aspera	Compositae	B+, M	Aq, Alc	Fl, L	41
Liatris chapmanii	Compositae	Y	—	L, St	124
Liatris paniculata	Compositae	Y	—	Fl, L	138
Ligustrum nepalense	Oleaceae	B+	O	E	133
Ligustrum vulgare	Oleaceae	B+	Aq	L, E	171, 120, 133
Ligustrum walkeri	Oleaceae	B+	O	E	133
Lilium harrisii	Liliaceae	M	Aq	L	120
Lilium longiflorum	Liliaceae	B+	Aq	Fl	42
Limonium carolinianum	Plumbaginaceae	Y	—	L	138
Linaria linaria	Scrophulariaceae	B+, B—	E	O	16
Linaria vulgaris	Scrophulariaceae	B+, B—	Aq	Fl, L	40, 120
Lindera benzoin	Lauraceae	M	Alc	L, St	119
Linnaea borealis	Caprifoliaceae	B+	Ac, Aq	O	10
Linum flavum	Linaceae	B+	Aq	R	120
Lippia lanceolata	Verbenaceae	B+, B—	E	O	16
Liriodendron tulipifera	Magnoliaceae	B+	Aq, —	L	124, 171
Loeselia coccinea	Polemoniaceae	B+, B—	S	O	58
Lolium perenne	Gramineae	B+, B—	O	L	172
Lomatia silaifolia	Proteaceae	B+	Aq	Fl	4
Lonas inodora	Compositae	M	Aq	R, St	120
Lonicera canadensis	Caprifoliaceae	B+	Ac, Alc	O	123
Lonicera interrupta	Caprifoliaceae	B+, B—, M	EJ	E	5, 71
Lonicera periclymenum	Caprifoliaceae	B+, B—	O	L	171
Lonicera pileata	Caprifoliaceae	B+, B—	O	O	168
Lonicera subspicata	Caprifoliaceae	B+, M	EJ	E	5, 71
Lonicera tatarica	Caprifoliaceae	B—	O	Fr	55
Lonicera xylosteum	Caprifoliaceae	B+, B—	O	O	40
Lotus argyraeus	Leguminosae	M	EJ	O	5
Ludwigia alternifolia	Onagraceae	B+, Y	Aq, +, —	Fr, L	138
Ludwigia brevipes	Onagraceae	Y	Aq, —	Fl, L	138
Lunaria annua	Cruciferae	B+, B—	O	R	133
Lupinus breweri	Leguminosae	M	EJ	O	5
Lupinus excubitus	Leguminosae	M	EJ	O	5
Lupinus hirsutus	Leguminosae	M	Alc, Aq	Fl, L, R	120
Lupinus luteus	Leguminosae	M	O	Fl, L, R	40
Lupinus polyphyllus	Leguminosae	B+, M	Alc, Aq, Ac	L, R, St	171, 120, 10
Lupinus villosus	Leguminosae	Y	—	L	138
Luzula multiflora	Juncaceae	B+	Ac	O	123
Lycium cooperi	Solanaceae	M	EJ	O	5
Lycopersicum esculentum	Solanaceae	B+, B—, F	Alc, Alm, Aq, +, EJ	Fr, L, St, Sl, R	12, 38, 66, 73, 112, 39, 121, 157
Lycopersicum pimpinellifolium	Solanaceae	B+, B—, F	Alc, Alm, +	L	38, 73, 121, 39
Lyonia fruticosa (*Xolisma fruticosa*)	Ericaceae	Y	Aq	L, St	138
Lyonia ligustrina	Ericaceae	M	Alc	L, St, Fr	119

Plant Name	Family	Activity	Type of Extract	Plant Part Tested	Ref's
Lysimachia thrysifolia	Primulaceae	B+	O	L	40
Lythrum californicum	Lythraceae	B+	EJ	E	71
Lythrum salicaria	Lythraceae	B—	O	O	40
	M				
Maclura pomifera	Moraceae	B+, B—, F	Ac, Alc, Aq	B, Fr, L, St	42, 132, 77, 101, 85
Madia elegans	Compositae	B+, B—	+, E, S	O	16
Magnolia acuminata	Magnoliaceae	B+, M	Alc, Aq	E, Fl, Fr, L, St	42, 133
Magnolia grandiflora	Magnoliaceae	B+	—	L, St, E	138, 133
Magnolia liliflora	Magnoliaceae	Y	Aq, —	Fl, L	138
Mahonia fortunei	Berberidaceae	B+	O	O	133
Mahonia fremonti	Berberidaceae	B+	Alc	L, St	119
Malacothrix californica	Compositae	B+	EJ	E	71
Malacothrix saxatilis	Compositae	B+	EJ	E	71
Malcolmia maritima	Cruciferae	B+, B—	EJ	S, Sl	133, 66
Mallotus philippinensis (*Croton coccineus*)	Euphorbiaceae	B+, B—	Ac	O	77
Malus bracteata	Rosaceae	B+, M	Alc, Aq	L	42
Malus prunifolia (*Pyrus prunifolia*)	Rosaceae	B+, B—	Ac, Alc, Aq	O	123
Malus pumila	Rosaceae	B+, B—, M	Alc, Aq	Fr, L	42
Malus purpurea	Rosaceae	B+, M	Alc, Aq	L	42
Malus scheideckeri	Rosaceae	B+, M	Aq	Fr, L, St	42
Malus toringoides (*Pyrus toringoides*)	Rosaceae	B+	Ac, Alc, Aq	O	123
Malus zumi (*Pyrus zumi*)	Rosaceae	B+	Ac	O	123
Malva rotundifolia	Malvaceae	M	Aq	Fr, L, R, St	42
Malvaviscus grandiflorus	Malvaceae	Y	Aq	L	124
Manfreda virginica	Amaryllidaceae	B—	—	L	138
Mascagnia macroptera	Malpighiaceae	B+, B—	Alc	L	119
Matricaria chamomilla	Compositae	B—, M	Alc, Aq	Fl	41, 55
Matricaria inodora	Compositae	B+, B—	O	L	171
Matthiola annua	Cruciferae	B+, B—	O	O	133
Matthiola bicornis	Cruciferae	B+, B—	O	S	133
Matthiola incana	Cruciferae	B+, B—	O	O	133
Medeola virginiana	Liliaceae	B+	Ac, Alc, E	O	123
Medicago lupulina	Leguminosae	M	Aq	E	42
Medicago sativa	Leguminosae	M, B—	Aq, E	E	42, 10
Melaleuca hypericifolia	Myrtaceae	B+	Aq	Fl	4
Melaleuca leucadendron	Myrtaceae	M	Alc	Fl, Fr, L	41
Melaleuca platycalyx	Myrtaceae	B+	Aq	L	4
Melaleuca squarrosa	Myrtaceae	B+	Aq	Fl	4
Melaleuca violacea	Myrtaceae	B+	Aq	L	4
Melaleuca wilsonii	Myrtaceae	B+	Aq	Fl	4
Melanthera hastata	Compositae	Y	Aq, —	Fl, L	138
Melia azadirachta (*M. azedarach*)	Meliaceae	B—, M	O	L, B, S	26, 154
Melilotus alba	Leguminosae	B+, B—, M	E, —, Aq, Ac	Fl, L, R, St	113, 119, 42, 10
Melilotus officinalis	Leguminosae	M	Aq	L	119
Melothria charantia	Cucurbitaceae	B+, M	Alc	L	119
Melothria pendula	Cucurbitaceae	Y	Aq, —	Fr, L	138
Meibomia canadensis	Leguminosae	B+, B—	+, —, E, S	O	16
Meibomia rigida	Leguminosae	B+, B—	+, S	O	16
Menispermum canadense	Menispermaceae	B+, B—, M	Alc, Alm, Aq	R	56, 55
Mentha sylvestris	Labiatae	B+	O	Fl, L	55

Plant Name	Family	Activity	Type of Extract	Plant Part Tested	Ref's
Menyanthes trifoliata	Gentianaceae	B+	Ac, Al, Aq, B, E	O	10
Mercurialis perennis	Euphorbiaceae	B+	O	Fl, L, R	40
Metasequoia glystostroboides	Taxodiaceae	M	Alc	L	41
Michelia fuscata	Magnoliaceae	B+	O	E	133
Mikania scandens	Compositae	Y	+	Fl, L	138
Milium effusum	Gramineae	B—	O	O	40
Mimosa pudica	Leguminosae	B+, M	Aq	L, R	120
Mimulus longiflorus	Scrophulariaceae	B+	EJ	E	71
Mimulus ringens	Scrophulariaceae	B+	+, E	O	16
Mirabilis froebelii	Nyctaginaceae	M	EJ	O	5
Mirabilis laevis	Nyctaginaceae	M	EJ	O	5
Mirabilis nyctaginea	Nyctaginaceae	M	Aq	Fl, St	41
Mischogyne michelioides	Annonaceae	B+, B—	O	O	133
Mitchella repens	Rubiaceae	B+, B—	+	O	16
Mollugo verticillata	Aizoaceae	B—	S	O	16
Monarda fistulosa	Labiatae	M	Aq	L, St	42
Monarda pectinata	Labiatae	B+	Aq	R	42
Monarda punctata	Labiatae	B+	Aq, —	E, Fl, L	55, 138
Monotropa uniflora	Monotropaceae	B+	Aq, Ac, Al, E	St	42, 10
Monstera deliciosa	Araceae	B+	Alc	Fl, L	120
Moringa pterygosperma (*M. oleifera*)	Moringaceae	B+, B—, M, F	Al	R	111, 145
Morus alba	Moraceae	B+, Y	Aq, —	L, St	171, 42, 138
Mundulea suberosa	Leguminosae	B+, M	Alc	Fr, L	119
Murraya exotica	Rutaceae	B+	Alc	L	119
Murraya paniculata	Rutaceae	M	Alc	Fl, L	41
Musa sapientum	Musaceae	B+, B—, F	Alm	L	151
Muscadinia rotundifolia	Vitaceae	Y	Aq, —	L	124
Muscari botryoides	Liliaceae	M	Aq	L	42
Mycelis muralis (*Lactuca muralis*)	Compositae	B+	O	O	40
Myrica asplenifolia (*Comptonia peregrina*)	Myricaceae	M, B+, B—	Alc, Aq	L, St, Fl	55, 42
Myrica gale	Myricaceae	B+	Ac, Al, Aq, E	O	10
Myrica pennsylvanica	Myricaceae	B+, B—	Aq	O	10
Myrica peregrina	Myricaceae	B+	—	O	113
Myriophyllum pinnatum	Haloragidaceae	Y	—	L, St	138
Myroxylon balsamum	Leguminosae	M	Alc	exudate	41
Myroxylon pereirae	Leguminosae	M	Alc	exudate	41
Myrtus communis	Myrtaceae	B+, B—, M	Aq, Alc	L, R, St	168, 41, 42
		N			
Nabalus altissima (*Prenanthes altissima*)	Compositae	B+, B—	+, E	L, S, St	16
Nama quadrivalve	Hydrophyllaceae	B+, B—, Y	+, —	L, Rh	124
Nandina domestica	Berberidaceae	Y	—	L	124
Napaea dioica	Malvaceae	B+	Aq	St	120
Navarretia squarrosa (*Gilia squarrosa*)	Polemoniaceae	B+, B—	E	O	16
Nelumbo lutea	Nymphaeaceae	B—, Y	Aq, —	L, petiole	124
Nelumbo nelumbo (*Nelumbium nelumbo*)	Nymphaeaceae	B+, B—	S	Fl, L, St	16
Nephthytis afzelii	Araceae	B+, B—, M	Aq	L	41
Nerium oleander	Apocynaceae	M	Aq	L	120
Nicotiana trigonophylla	Solanaceae	M	EJ	O	5
Nothoscordum bivalve	Liliaceae	Y	Aq, —	Fl	138
Nuphar variegatum	Nymphaeaceae	B+	Ac, Alc	O	123

Plant Name	Family	Activity	Type of Extract	Plant Part Tested	Ref's
Nymphaea odorata	Nymphaeaceae	B+, B—	Ac, Al, Aq, E	O	10
O					
Ocimum basilicum	Labiatae	B+, M	Aq	S	42
Ocimum canum	Labiatae	M	SD	L	64
Ocimum sanctum	Labiatae	M	SD	L	63
Oenothera biennis	Onagraceae	B+, B—, M	Ale, Aq, —, E	L, St, Fl, Fr, R	16, 41, 113, 40
Oenothera hookeri	Onagraceae	B+	EJ	E	71
Oenothera parviflora	Onagraceae	Y	Aq, —	L	138
Ophiscaulon cissampeloides	Passifloraceae	B+	O	O	133
Orchis impudica	Orchidaceae	B+	O	Fl, L	40
Orchis mascula	Orchidaceae	B+	O	Fl, L	40
Orontium aquaticum	Araceae	B+, B—	Aq, —	L	138
Osmunda regalis	Osmundaceae	B—	O	O	40
Oxalis corniculata	Oxalidaceae	B+	EJ	E	71
Oxalis europaea	Oxalidaceae	B+, B—	Ac, Al, Aq, E	O	10
Oxydendrum arboreum	Ericaceae	M	Ale	L	119
Oxytheca parishii	Polygonaceae	M	EJ	O	5
Oxytheca perfoliata	Polygonaceae	B+, M	EJ	E	5, 71
P					
Pachysandra procumbens	Buxaceae	B+, M	Ale, Aq	Fl, L, St	42
Pachysandra terminalis	Buxaceae	M	Ale, Aq	L, St	42
Padus virginiana	Rosaceae	Y	—	L	124
Paeonia arborea	Ranunculaceae	B+	O	O	168
Paeonia brownii	Ranunculaceae	B+, M	EJ	E	5, 71
Paeonia officinalis	Ranunculaceae	B+, B—	Aq	R, St	42, 55
Paris quadrifolia	Liliaceae	B+	O	O	40
Parthenium hysterophorus	Compositae	B—	S	O	58
Parthenocissus quinquefolia	Vitaceae	B+, Y	Ale, —	L, St, R	119, 124
Parthenocissus tricuspidata	Vitaceae	B+, B—		Fr, L, St	120
Passiflora caerulea	Passifloraceae	B+, M	Aq	L	42
Passiflora suberosa	Passifloraceae	B+, B—	O	O	133
Paulownia fortunei	Scrophulariaceae	B+	Ale	L	41
Paulownia tomentosa	Scrophulariaceae	B+	Ale	Fr	119
Pedilanthus tithymaloides	Euphorbiaceae	B+	Ale, Aq	R	42
Pelargonium domesticum	Geraniaceae	B+, B—	Aq	Fl, L	120
Pelargonium zonale	Geraniaceae	M	Aq	L, St	41
Pellaea andromedaefolia	Polypodiaceae	M	EJ	O	5
Pellaea mucronata	Polypodiaceae	M	EJ	O	5
Pennisetum ruppelii	Gramineae	B+, B—	Ale, Aq	R	42
Penstemon antirrhinoides	Scrophulariaceae	B+, M	EJ	E	71, 5
Penstemon bridgesii	Scrophulariaceae	B+	EJ	E	71
Penstemon caesius	Scrophulariaceae	B+	EJ	E	71
Penstemon centranthifolius	Scrophulariaceae	M	EJ	O	5
Penstemon cordifolius	Scrophulariaceae	B+, B—	EJ	E	71
Penstemon grandiflorus	Scrophulariaceae	B+	Aq	R, St	120
Penstemon labrosus	Scrophulariaceae	B+	EJ	E	71
Penstemon ternatus	Scrophulariaceae	B+, B—	EJ	E	71
Penthorum sedoides	Crassulaceae	B+, B—	E	O	16
Peperomia obtusifolia	Piperaceae	B+	Ale	L, R, St	42
Persea americana	Lauraceae	B+, B—, F, M	Ac, Aq	Fr, R, S, St	93, 77, 78, 79, 41, 132
Persea pubescens	Lauraceae	B+	—	L	138
Persicaria hydropiper (*Polygonum hydropiper*)	Polygonaceae	B+, B—	+, E	O	16
Persicaria opelousana (*Polygonum opelousana*)	Polygonaceae	B+, B—	+, E, S	O	16
Petalostemum corymbosus (*Kuhnistera pinnata*)	Leguminosae	Y	—	Fl, L	138
Petalostemum purpureum	Leguminosae	B+	Ac	E	88

Plant Name	Family	Activity	Type of Extract	Plant Part Tested	Ref's
Petasites hybridus	Compositae	B—	O	O	40
Petasites japonicus	Compositae	B+, M	Alc, Aq	Fl, L, R	120
Petteria ramontacea	Leguminosae	B+, M	Alc	L	119
Phacelia fremontii	Hydrophyllaceae	M	EJ	O	5
Phaethusa virginica (*Verbesina virginica*)	Compositae	Y	Aq, —	L	138
Phalaris arundinacea	Gramineae	M	Aq	L	41
Phalaris minor	Gramineae	M	EJ	O	5
Phaseolus vulgaris	Leguminosae	B+, B—	Al	Fr	112
Phellodendron amurense	Rutaceae	B+, M	Alc, Aq	Fr	41
Philibertia hirtella (*Funastrum hirtellum*)	Asclepdiadaceae	M	EJ	O	5
Phleum nodosum	Gramineae	B+	O	L	172
Phleum phleoides	Gramineae	B+	O	L	172
Phleum pratense	Gramineae	B+, M	Aq	Fl, L,R	41, 172
Photinia arbutifolia (*Heteromeles arbutifolia*)	Rosaceae	M	EJ	O	5
Phylis heterophylla	Solanaceae	B+, B—	+	L, St	113
Phyllanthus caroliniensis	Euphorbiaceae	B+, B—	Aq	L	42
Physalis alkekengi	Solanaceae	B+, M	Aq	L, St	42
Physalis heterophylla	Solanaceae	B+	+, E, S	Fr, L, St	16
Physalis subglabrata	Solanaceae	B+, B—	+, E	O	16
Phytolacca americana	Phytolaccaceae	B+, B—	+, —, Aq	L, St	113, 120
Picea abies	Pinaceae	B+, B—, M	Alc, Aq	L, S, St	41, 42
Picea glauca	Pinaceae	B+, M	Alc, Aq	L, St	42
Picea pungens	Pinaceae	B+, B—, M	Alc, Aq	L, St	42
Picramnia pentandra	Simarubaceae	B+	Alc	L, Fr	119
Pilea microphylla	Urticaceae	M	Aq	L	42
Pimpinella saxifraga	Umbelliferae	B—	O	O	40
Pinus cembroides	Pinaceae	M	EJ	O	5
Pinus contorta	Pinaceae	B+, M	EJ	E	5, 71
Pinus coulteri	Pinaceae	B+, M	EJ	E	5, 71
Pinus densiflora	Pinaceae	B+, B—, M	Alc, Aq	L, St	42
Pinus echinata	Pinaceae	B+	Alc	Fr	41
Pinus lambertiana	Pinaceae	B+, B—, M	EJ	E	5, 71
Pinus mugo	Pinaceae	B+, M	Alc	St	41
Pinus nigra	Pinaceae	B+, B—, M	Alc, Aq	Fr, L, St	41, 42
Pinus ponderosa	Pinaceae	B+, B—, M	EJ	E	5, 71
Pinus resinosa	Pinaceae	B+, M	Alc, Aq	Fr, St	41, 42
Pinus strobus	Pinaceae	B+, B—	+	L	113
Piper betle	Piperaceae	M	SD	L	64
Pistacia chinensis	Anacardiaceae	B+	Alc	Fr, L	119
Pistacia vera	Anacardiaceae	B+	Alc	Fr	119
Pityrogramma triangularis	Polypodiaceae	B+, M	EJ	E	71, 5
Plantago juncoides	Plantaginaceae	B+	Al	O	10
Plantago lanceolata	Plantaginaceae	B+, B—	Al, EJ	E, L	34, 40, 71
Plantago media	Plantaginaceae	B+	O	L	171
Platanus racemosa	Platanaceae	M	EJ	O	5
Pluchea sericea	Compositae	M	EJ	O	5
Plumbago europaea	Plumbaginaceae	B+, B—	O	L	171
Plumeria bicolor	Apocynaceae	B+	O	O	133
Plumeria multiflora	Apocynaceae	B+, F	Al	R	114
Poa chaixi	Gramineae	B+, B—	O	L	172
Poa nemoralis	Gramineae	B+	O	L	172
Poa palustris	Gramineae	B+	O	L	172
Poa pratensis	Gramineae	B+, B—	O	L	172
Podophyllum peltatum	Berberidaceae	B+, B—, M	+, —, Aq	L, St, Fl	113, 42
Polygala lutea	Polygalaceae	B—, Y	Aq, +, —	Fl, L	138

Plant Name	Family	Activity	Type of Extract	Plant Part Tested	Ref's
Polygonatum commutatum	Liliaceae	B+, B—	+, E	Fr, L	16
Polygonella polygama	Polygonaceae	Y	—	Fl, L	138
Polygonum cuspidatum	Polygonaceae	B+, B—	Ac, Alc	O	123
Polygonum hydropiper (*Persicaria hydropiper*)	Polygonaceae	B+, B—	+, E	O	16, 40
Polygonum hydropiperoides	Polygonaceae	B+	Aq	Fl, L, R, St	41
Polygonum lapathifolium	Polygonaceae	B+, M	Alc, Aq	Fl, L, R, St	41
Polygonum persicaria	Polygonaceae	B+, M	Aq	Fl, L	41, 55
Polygonum punctatum	Polygonaceae	B+	Aq	Fl, L, R, St	41
Polygonum sachalinense	Polygonaceae	B+	Aq	L, St	120
Polygonum scandens	Polygonaceae	B+, B—	E	O	16
Polygonum virginianum	Polygonaceae	B+	E	O	16
Polypodium vulgare	Polypodiaceae	B—	O	O	40
Polystichum acrostichoides	Polypodiaceae	B+	E	O	123
Polystichum braunii	Polypodiaceae	B+	Ac	O	123
Polystichum munitum	Polypodiaceae	B+, M	EJ	E	71, 5
Pomaderris elliptica	Rhamnaceae	B+	Aq	Fl	4
Poncirus trifoliata	Rutaceae	Y	+, —	L	124
Pongamia pinnata	Leguminosae	M	Alc	Fr, L	119
Pontederia cordata	Pontederiaceae	B+, B—	+	L	124
Populus alba	Salicaceae	B+, M	Alc, Aq	L, R, St, B	119
Populus balsamifera	Salicaceae	B+	Ac, Al, B, E	O	10
Populus candicans	Salicaceae	F	Aq	B	108
Populus deltoides	Salicaceae	B+	Ac, Al, B, E	O	10
Populus fremontii	Salicaceae	F	EJ	O	5
Populus tacamahaca	Salicaceae	B+, B—, M	E, Alc, Aq	buds, Fl, St	31, 42
Portulaca oleraceae	Portulacaceae	B—	Aq, E	O	10, 157
Potalonyx thurberi	Loasaceae	B+, B—	EJ	E	71
Potentilla argentea	Rosaceae	B+	Ac, Aq	O	10
Potentilla bolanderi	Rosaceae	B+	EJ	E	71
Potentilla erecta	Rosaceae	B—	O	Fl, L, R	40
Potentilla pennsylvanica	Rosaceae	B+, M	Aq	E	42
Potentilla wheeleri	Rosaceae	B+	EJ	E	71
Pothos aureus (*Scindapsus aureus*)	Araceae	B+	Aq	L	120
Prenanthes alba	Compositae	B+, M	Aq	Fl, L, St	42
Prenanthes altissima (*Nabalus altissima*)	Compositae	B+, B—	+, E	L, S, St	16
Primula elatior	Primulaceae	B+	O	L	40
Primula malacoides	Primulaceae	B+, M, B—, F	Alc, Aq	E, Fl, L, R	120, 42, 167
Primula obconica	Primulaceae	B+, M	Aq	Fl, R, L	41, 120
Primula veris	Primulaceae	B—	O	O	40
Proboscidea jussieui	Martyniaceae	B+, M	Alc, Aq	L	41
Prosopis ruscifolia	Leguminosae	B+, B—, F	O	L	22
Prunus amygdalus	Rosaceae	B+, M	Alc, Aq	R, St	119
Prunus caroliniana	Rosaceae	B+, B—	Aq, +, —	L	138
Prunus cerasus	Rosaceae	M	Aq	L, St	41
Prunus cerasifera	Rosaceae	B+, B—, M	Alc, Aq	L, St	41
Prunus domestica	Rosaceae	B+, B—, M	Alc, Aq	Fr, L, R, St	55, 41, 42, 123
Prunus emarginata	Rosaceae	B+, B—	E	Fr, L	16
Prunus ilicifolia	Rosaceae	F, M	EJ	O	5
Prunus persica	Rosaceae	B+, M	Aq	St	42
Prunus serotina	Rosaceae	B+, B—	Aq, +, —	L	138
Prunus umbellata	Rosaceae	B+, B—	Aq, —	L	138

Plant Name	Family	Activity	Type of Extract	Plant Part Tested	Ref's
Pseudotsuga taxifolia	Pinaceae	B+, B— M	Alc, Aq	L, St	42
Psidium guajava	Myrtaceae	B+, B—	Aq	L, R, St	119
Psidium molle	Myrtaceae	M	Alc	L	41
Psilotum triquetrum	Psilotaceae	B+, B—	O	O	133
Ptelea trifoliata	Rutaceae	M	Aq	L	120
Pteridium aquilinum	Polypodiaceae	B+	EJ	E	71
Pterocaulon undulatum	Compositae	Y	Aq, —	L	138
Pterostegia drymariodides	Polygonaceae	M	EJ	O	5
Pueraria thunbergina	Leguminosae	Y	Aq	L	124
Pulmonaria officinalis	Boraginaceae	B+	—	R, St	40, 55
Punica granatum	Punicaceae	B+	Alc	L	119
Pyracantha coccinea	Rosaceae	B+	Aq	L	120
Pyracantha crenato-serrato	Rosaceae	B+, M	Alc, Aq	L, R, St	42
Pyrola rotundifolia	Pyrolaceae	B+	Ac, E	O	123
Pyrola secunda	Pyrolaceae	B+	Ac, Alc	O	123
Pyrularia pubens	Santalaceae	M	Alc	Fr	119
Pyrus americana	Rosaceae	B+, B—	+, —	Fr	113
Pyrus atrosanguinea (*Malus halliana*)	Rosaceae	B+, B—, M	Alc, Aq	Fr, L	120
Pyrus aucuparia (*Sorbus aucuparia*)	Rosaceae	B+	Ac, Al, Aq	O	10
Pyrus communis	Rosaceae	B+, B—, Y	Aq, —	Fr	138
Pyrus malus	Rosaceae	B+, B—	Ac, Al, B, E	L	10, 122
Pyrus prunifolia	Rosaceae	B+, B—	Ac, Alc, Aq		123
Pyrus toringoides	Rosaceae	B+	Ac, Alc, Aq		123
Pyrus zumi	Rosaceae	B+	Ac		123
		Q			
Quercus borealis	Fagaceae	B+, M	Aq	L, St	41
Quercus coccinea	Fagaceae	B+, M	Aq	L, St	41
Quercus dumosa	Fagaceae	B+, M	EJ	E	5, 71
Quercus kelloggii	Fagaceae	B+	EJ	E	71
Quercus marilandica	Fagaceae	B+, Y	+, —	L	124
Quercus muhlenbergi	Fagaceae	B+, M	Alc, Aq	L	42
Quercus velutina	Fagaceae	B+, B—	Alc, Aq	L, St	42
Quercus virginiana	Fagaceae	B—	—	L	138
Quercus wislizenii	Fagaceae	B+, M	EJ	E	5, 71
		R			
Rafinesquia neomexicana	Compositae	B+	EJ	E	71
Ranunculus abortivus	Ranunculaceae	B+, B—, M, Y	Aq, +, —	E, L	42, 138
Ranunculus acer	Ranunculaceae	B+, B—	O	O	40
Ranunculus acris	Ranunculaceae	B+, B—	Ac, E, S	O	10, 16, 133
Ranunculus auricomus	Ranunculaceae	B+, B—	O	O	40
Ranunculus bulbosus	Ranunculaceae	B+, B—	O	O	40, 133
Ranunculus cymbalaria	Ranunculaceae	B+, B—	EJ	E	71
Ranunculus flammula	Ranunculaceae	B+, B—	O	O	133, 40
Ranunculus lanuginosus	Ranunculaceae	B+, B—	O	O	40
Ranunculus lingua	Ranunculaceae	B+, B—	O	O	133
Ranunculus palmatus	Ranunculaceae	Y	Aq, +, —	L	138
Ranunculus pennsylvanicus	Ranunculaceae	B+, B—, M	Aq	E	42
Ranunculus recurvatus	Ranunculaceae	B+, B—	S	O	16
Ranunculus repens	Ranunculaceae	B+, B—	O	O	40
Ranunculus septentrionalis	Ranunculaceae	B+, B—, M, Y	Alc, Aq, +, —, S	O	16, 42, 124
Raphanus raphanistrum	Cruciferae	B+, B—	O	O	40

Plant Name	Family	Activity	Type of Extract	Plant Part Tested	Ref's
Raphanus sativus	Cruciferae	B+, B—, F	Aq	S	30, 74, 75, 76, 109
Raphanus rugosum	Cruciferae	B+, B—	Aq	O	4
Ratibida pinnata (*Lepachys pinnata*)	Compositae	B+, B—	E, S	O	16
Ravenia humilis	Rutaceae	M	Aq	L	120
Regelia ciliata	Myrtaceae	B+	Aq	Fl, Fr, L	4
Regelia grandiflora	Myrtaceae	B+	Aq	Fl	4
Reseda lutea	Resedaceae	B+	O	E	133
Reseda odorata	Resedaceae	B+, M	Aq	L, St	42
Rhamnus catharticus	Rhamnaceae	B+, M, B—	Aq	L, St, Fr	41, 133, 40
Rhamnus crocea	Rhamnaceae	B+	EJ	E	71
Rhamnus frangula	Rhamnaceae	B+	Ac, Alc	O	123
Rhamnus utilis	Rhamnaceae	B+	Alc	Fr	41
Rheum officinalis	Polygonaceae	M	Alc, Aq	R	55
Rheum rhaponticum	Polygonaceae	B+, B—	Al	petiole	112
Rhexia alifanus	Melastomaceae	B—	—	L	138
Rhododendron canadense	Ericaceae	B+, B—	Ac, Al, E	O	10
Rhododendron indicum	Ericaceae	B+	Aq	Fl, L	120
Rhododendron maximum	Ericaceae	B+, B—, M	Alc, Aq	Fl, L, S, St	41
Rhododendron obtusum	Ericaceae	B+, M	Alc, Aq	L, R, St	119
Rhododendron sp.	Ericaceae	B+	Ac	O	123
Rhoeo discolor	Commelinaceae	M	Aq	Fl	42
Rhus aromatica	Anacardiaceae	B+, M, B—	Aq, +, —	Fl, L	41, 16
Rhus copallina	Anacardiaceae	B—, Y, M	—, Alc	L, St, Fl	124, 119
Rhus crenata	Anacardiaceae	B+, B—	Ac	O	77
Rhus glabra	Anacardiaceae	B+, B—, M	Alc, Aq	Fr	42
Rhus hirta	Anacardiaceae	B+, B—	+, Aq, E	Fl, L, St	15, 16
Rhus integrifolia	Anacardiaceae	B+	Alc	L	119
Rhus laurina	Anacardiaceae	M	EJ	O	5
Rhus ovata	Anacardiaceae	M	EJ	O	5
Rhus trilobata	Anacardiaceae	B+, M	EJ	E	5, 71
Rhus typhina	Anacardiaceae	B+, B—	+, Aq, E	B, L, Fl, St	113, 15, 16
Ribes aureum	Saxifragaceae	B+	O	O	168
Ribes bracteosum	Saxifragaceae	B+, B—	E, S	L, St	16
Ribes cereum	Saxifragaceae	B+, M	EJ	E	5, 71
Ribes grossularia	Saxifragaceae	B+	O	O	168
Ribes hirtellum	Saxifragaceae	M	Aq	Fr	41
Ribes nevadense	Saxifragaceae	B+	EJ	E	71
Ribes nigrum	Saxifragaceae	Ph, V	O	Fr	35, 36
Ribes roezlii	Saxifragaceae	B+, B—, M	EJ	E	5, 71
Ribes rubrum	Saxifragaceae	Ph, V	O	Fr	35, 36
Ribes sanguineum	Saxifragaceae	B+	O	L	171
Ribes sativum	Saxifragaceae	B+, M	Alc, Aq	Fr	41
Ricinus communis	Euphorbiaceae	Y, M	EJ, —, Aq	L	123, 124, 41
Ridan alternifolius (*Actinomeris alternifolia*)	Compositae	B+, B—	S	Fl, L, St	16
Robinia pseudo-acacia	Leguminosae	B+, B—, M	Alc, Ac, Aq	Sl, L, St	132, 120
Rosa californica	Rosaceae	B+	EJ	E	71
Rosa canina	Rosaceae	B+, B—, M	Alc, Aq	Fl, L, St	120
Rosa laevigata	Rosaceae	Y	Aq, —	L	138
Rosa multiflora	Rosaceae	B+, M	Aq	Fl, L, St	120
Rubus hispidus	Rosaceae	B+	Aq	R, St	119
Rubus odoratus	Rosaceae	B+	Ac, Alc	O	123
Rudbeckia hirta	Compositae	B+	E	L	16

Plant Name	Family	Activity	Type of Extract	Plant Part Tested	Ref's
Rudbeckia laciniata	Compositae	B+	Ac, Al, B	O	10
Rumex acetosella	Polygonaceae	B+	E	O	10
Rumex crispus	Polygonaceae	B—	Alc	S	42
Ruta graveolens	Rutaceae	B+	O	L	171
		S			
Sabina silicicola (*Juniperus silicicola*)	Cupressaceae	B+	—	L, St	124
Sagittaria cuneata	Alismaceae	B+	E	O	10
Sagittaria lancifolia	Alismaceae	B+, B—	Aq, +, —	L	138
Sagittaria latifolia	Alismaceae	B+	E	L, St	16
Salazaria mexicana	Labiatae	B+	EJ	E	71
Salix caprea	Salicaceae	M	Alc	Fl	120
Salix exigua	Salicaceae	M	EJ	O	5
Salix lasiolepis	Salicaceae	B+, B—, M	EJ	E	5, 71
Salix purpurea	Salicaceae	B+	Ac, Alc, E	O	123
Salix viminalis	Salicaceae	B+	O	O	40
Salvia apiana	Labiatae	B+	EJ	E	71
Salvia carnosa	Labiatae	B+	EJ	E	71
Salvia farinacea	Labiatae	M	Aq	Fl	41
Salvia mellifera	Labiatae	B+, M	EJ	E	5, 71
Salvia officinalis	Labiatae	B+, M	Alc, Aq	L, R, St	55
Salvia pachyphylla	Labiatae	B+	EJ	E	71
Salvia sp.	Labiatae	B+, B—	Ac	O	77
Sambucus canadensis	Caprifoliaceae	B+, B—	E, S	L	16
Sambucus glauca	Caprifoliaceae	B+, B—	+, —, E	Fl, L, St	16
Sambucus pubens	Caprifoliaceae	M	Aq	L	41
Sambucus simpsonii	Caprifoliaceae	Y	Aq, —	L	124
Sanguinaria canadensis	Papaveraceae	B+, M, B—	Ac, +, Alc, Aq, E	R	119, 123, 77, 55, 16
Sanguisorba tenuifolia (*Poterium tenuifolium*)	Rosaceae	B—	Alc	L	120
Sanicula crassicaulis	Umbelliferae	B+	S	Fl, L, St	16
Sanicula gregaria	Umbelliferae	B+, B—	S	O	16
Santolina chamaecyparissus	Compositae	B+, M	Alc, Aq	Fl, L, R	120
Sapium sebiferum	Euphorbiaceae	B+	Alc	Fr, L	119
Saponaria officinalis	Caryophyllaceae	B+, B—	+	O	16
Sarcodes sanguinea	Ericaceae	B+, B—, M	EJ	E	5, 71
Sarracenia drummondii	Sarraceniaceae	B—, Y	—	L	124
Sarracenia flava	Sarraceniaceae	B—, Y	+, —	L	124
Sarracenia mandiana	Sarraceniaceae	B+, B—, Y	—	L	124
Sassafras officinale	Lauraceae	B+, B—	Ac	R	77
Sassafras variifolium	Lauraceae	Y	+	L	124
Satureja vulgaris	Labiatae	B+, B—	O	O	40
Savia sessiliflora	Euphorbiaceae	M	Alc	Fr, L	119
Saxifraga rosacea	Saxifragaceae	B—	O	O	40
Saxifraga sarmentosa	Saxifragaceae	B+	Aq	E	120
Scabiosa atropurpurea	Dipsaceae	B+, M	Aq	St	120
Schinus terebinthifolia	Anacardiaceae	B+, M	Alc	Fr, L, St	119
Schismus barbatus	Gramineae	M	EJ	O	5
Schizanthus gracilis	Solanaceae	M	Aq	Fl	41
Schlumbergera truncata	Cactaceae	M	Aq	St	42
Schmaltzia crenata (*Rhus aromatica*)	Anacardiaceae	B+, B—	+, —	O	16
Sciadopitys verticillata	Taxodiaceae	B+, M	Alc, Aq	L, St	42
Scrophularia californica	Scrophulariaceae	B+	EJ	E	71
Scrophularia marylandica	Scrophulariaceae	B+, B—	E, S	O	16
Scrophularia vernalis	Scrophulariaceae	B+	O	L	171
Scutellaria galericulata	Labiatae	M	Aq	E	42

Plant Name	Family	Activity	Type of Extract	Plant Part Tested	Ref's
Secale cereale	Gramineae	B+, B—, F, Y	E, +	Sl	163, 164, 165
Sedum acre	Crassulaceae	B+	Aq	Fl, L, St	42
Sedum spectabile	Crassulaceae	B+, B—	Ac, Alc, E	E	132
Senecio californicus	Compositae	M	EJ	O	5
Senecio sylvaticus	Compositae	B—	S	O	16
Senecio viscosus	Compositae	B+	Ac, Alc, E	O	123
Serenoa repens	Palmaceae	Y, B+, B—	—, Ac	L	124, 77
Sericocarpus asteroides	Compositae	B+	E	O	16
Sericocarpus bifoliatus	Compositae	Y	—	Fl, L	138
Sesamum indicum	Pedaliaceae	M	Aq	S	44
Silene stellata	Caryophyllaceae	M	Aq	L, St	42
Silphium asteriscus	Compositae	B+, Y	Aq, —	L	138
Silphium laciniatum	Compositae	B—	Alc	St	120
Silphium perfoliatum	Compositae	M, B+	Aq, E, S	L, Fl, St	55, 16
Silphium terebinthinaceum	Compositae	B+, B—	E, S	L, S, St	16
Sisymbrium altissimum	Cruciferae	M, B+	Aq, E	E	42, 10
Sisyrinchium montanum	Iridaceae	B+	Ac, Alc	O	123
Smilacina racemosa	Liliaceae	B+	Ac, B	O	10
Smilax rotundifolia	Liliaceae	B+, B—	E	O	16
Solanum carolinense	Solanaceae	M	Aq	L	41
Solanum nigrum	Solanaceae	B—	O	O	40
Solanum pseudocapsicum	Solanaceae	M, B+	Alc, Aq	L, R	11, 42
Solanum tuberosum	Solanaceae	B+, B—, F	O	L, S, T	40, 38, 107
Solidago californica	Compositae	B+, M	EJ	E	5, 71
Solidago canadensis	Compositae	B+, B—	Al, Aq, E	L, St, Fl	10, 113, 120
Solidago flexicaulis	Compositae	B+	Ac	O	10
Solidago macrophylla	Compositae	B+	Ac, Alc	O	123
Solidago sempervirens	Compositae	B+	Al	O	10
Salsola pestifer	Chenopodiaceae	B+, B—	E	O	16
Sonchus palustris	Compositae	B+	O	O	133
Sorbus americana	Rosaceae	M	Aq	Fr	41
Sorbus aucuparia	Rosaceae	B+, Ph, V	Ac, Al, Aq	Fr	40, 10, 35, 36
Scutellaria lateriflora	Labiatae	B+	Ac, Al, E	O	10
Spartina pectinata	Graminae	B—	Aq	O	123
Spathiphyllum cannaefolium	Araceae	B+, B—	Aq	L	120
Spathyema foetida (*Symplocarpus foetidus*)	Araceae	B+, B—	E	L	16
Sphaeralcea ambigua	Malvaceae	M	EJ	O	5
Spinacia oleracea	Chenopodiaceae	Ph	O	L	35, 36
Spirea aruncus	Rosaceae	B+, B—	O	O	133
Spirea bullata	Rosaceae	B+	O	O	133
Spirea bumalda	Rosaceae	B+, B—	O	O	133
Spirea japonica	Rosaceae	B+, B—	O	O	133
Spirea latifolia	Rosaceae	B+, B—	+, Ac, Alc, Aq, B, E, S	Fl, L, R, St	10, 16, 41
Spirea thunbergii	Rosaceae	B+, B—, M	Alc, Aq	O	41, 133
Spirea tomentosa	Rosaceae	B—	+, E	O	16
Stachys alpina	Labiatae	B+	O	L	171
Stephanomeria exigua	Compositae	B+	EJ	E	71
Stephanomeria pauciflora	Compositae	B+	EJ	E	71
Stephanomeria virgata	Compositae	B+	EJ	E	71
Steriphoma ellipticum	Capparidaceae	B+	O	O	133
Steriphoma paradoxum	Capparidaceae	B+	O	O	133
Stifftia chrysantha	Compositae	B+	O	O	133
Stillingia aquatica	Euphorbiaceae	Y	Aq	Fl, L	138

Plant Name	Family	Activity	Type of Extract	Plant Part Tested	Ref's
Strobilanthes isophyllus	Acanthaceae	B+, M	Aq	L, R, St	41
Strophanthus glaber	Apocynaceae	M	Alc	L	119
Strophanthus hispida	Apocynaceae	M	E	R, St	132
Styrax japonica	Styracaceae	M	Alc	L	119
Symphoricarpos albus	Caprifoliaceae	B+, B—	EJ	E	71
Symphoricarpos racemosus	Caprifoliaceae	B+, B—	O	O	168
Symplocarpus foetidus (*Spathema foetida*)	Araceae	B+, B—	E	L	16
Syringa vulgaris	Oleaceae	B+, M, B—	Alc, Aq, Ac, E	Fl, L, St	120, 10, 41
Syzygium cuminii	Myrtaceae	B+	Alc	Fr, L	119
		T			
Tabebuia avellanedae	Bignoniaceae	B+, B—, M	O	St	54
Tabebuia sp.	Bignoniaceae	B+, B—, F	O	St	53
Tagetes erecta	Compositae	B+	Aq	Fl	42
Tagetes patula	Compositae	B+	Aq	Fl	120
Tanacetum vulgare	Compositae	B+	E	R	133, 16
Taraktogenos kurzii	Flacourtiaceae	B+, B—	O	O	133
Taraxacum officinale	Compositae	B+, M	Aq	L, R	42
Taxodium distichum	Taxodiaceae	B+, B—	Alc, Aq, Ac	L, St	42, 77
Taxus canadensis	Taxaceae	M	Alc, Aq	L	120
Taxus media	Taxaceae	B+, B—, M	Alc, Aq	L, St	42
Tecoma radicans	Bignonaceae	B+, B—	+, —	O	113
Teesdalia nudicaulis	Cruciferae	B+, B—	O	O	40
Tetradymia comosa	Compositae	B+	EJ	E	71
Tetradymia spinosa	Compositae	M	EJ	O	5
Teucrium chamaedrys	Labiatae	M	Alc	E	120
Thalictrum polygamum	Ranunculaceae	B+	Ac, B	O	10
Thlaspi arvense	Cruciferae	M	Aq	Fl, L, S	41
Thryallis brasiliensis	Malpighiaceae	B+, M	Alc, Aq	Fl, L, St	42
Thryallis glauca	Malpighiaceae	B+, M	Aq	L, St	42
Thuja occidentalis	Cupressaceae	B+, B—, F	Aq, Ac, Alc	L, St	123, 96, 77, 87, 42
Thuja orientalis	Cupressaceae	B+, B—	Alc, Aq	L, St	42
Thuja plicata	Cupressaceae	F	Aq, SD	St	3, 32, 33, 57, 146, 148
Thysanella fimbriata	Polygonaceae	Y	—	L	124
Thysanocarpus curvipes	Cruciferae	B+, B—, M	EJ	E	5, 71
Tillandsia balbisiana	Bromeliaceae	Y	+	E	138
Tillandsia usneoides (*Dendropogon usneoides*)	Bromeliaceae	B+	—	E	124
Tiniara scandens (*Polygonum scandens*)	Polygonaceae	B+, B—	E	O	16
Tinospora cardifolia	Menispermaceae	M	SD	L, St	64
Tithonia rotundifolia	Compositae	B+, B—	Aq	L, St	41
Tithymalopsis corollata (*Euphorbia corollata*)	Euphorbiaceae	B+, B—	E, S	L, St	16
Torilis anthriscus (*Caucalis anthricus*)	Umbelliferae	B+, B—	E	O	16
Tovara virginiana (*Polygonum virginianun*)	Polygonaceae	B+	E	O	16
Trachelospermum jasminoides	Apocynaceae	Y	—	L, St	124
Trachypogon plumosus	Gramineae	B+, B—	Aq	R	159
Tradescantia foliosa	Commelinaceae	B+, B—, Y	Aq, —	L	138
Trichostema dichotomum	Labiatae	B+	+	Fl, L	138
Trichostema lanatum	Labiatae	B+	EJ	E	71

Plant Name	Family	Activity	Type of Extract	Plant Part Tested	Ref's
Trichostema lanceolatum	Labiatae	B+	EJ	E	71
Trientalis europaea	Primulaceae	B+, B—	O	L	40
Trifolium hybridum	Leguminosae	M	Aq	E	55
Trifolium pratense	Leguminosae	M	Aq	Fl, L, R, St	41
Trifolium repens	Leguminosae	M	Aq	Fl, L	119
Trilisa paniculata (*Liatris paniculata*)	Compositae	Y	—	Fl, L	138
Trillium grandiflorum	Liliaceae	M	Aq	L	41
Triosteum aurantiacum	Caprifoliaceae	B+	Ac, Alc	O	123
Triosteum perfoliatum	Caprifoliaceae	B+, B—	+	L, R, St	16
Triticum aestivum	Gramineae	B+, B—, F, Y	E	Sl	165
Tropaeolum majus	Tropaeolaceae	B+, B—, F, Y	Aq, —	L	28, 138, 157, 158, 173
Tropaeolum peregrinum	Tropaeolaceae	B+, B—	EJ	Sl	66
Tulbaghia violacea	Liliaceae	B—, M	Aq	E	55
Tulipa acuminata	Liliaceae	B+, B—	Aq	Fl	120
Tulipa chrysantha	Liliaceae	B+, B—	O	E	133
Tulipa clasiana	Liliaceae	B+, B—	O	E	133
Tulipa cretica	Liliaceae	B+, B—	O	E	133
Tulipa forsteriana	Liliaceae	B+, B—	O	E	133
Tulipa gesneriana	Liliaceae	B+, B—, M	Alc, Aq	E, L, St, R, Fl	120, 168, 42, 133
Tulipa greigii	Liliaceae	B+, B—	O	E	133
Tulipa kaufmanniana	Liliaceae	B+, B—	O	E	133
Tulipa kolpatowskyana	Liliaceae	B+, B—	O	E	133
Tulipa linifolia	Liliaceae	B+, B—	O	E	133
Tulipa turkestanica	Liliaceae	B+, B—	O	E	133
Turritis glabra (*Arabis perfoliata*)	Cruciferae	B+, B—	O	Fl, L, R	40
Tussilago farfara	Compositae	B—	O	O	40
Typha domingensis	Typhaceae	B+, Y	Aq, —	L	138
Typha latifolia	Typhaceae	B+	E	O	16
		U			
Ulmus americana	Ulmaceae	F, M	Alc, Aq	St	138, 42
		V			
Vaccinium angustifolium	Ericaceae	B+, B—	Ac, Al, Aq, B, E	Fr, O	55, 10
Vaccinium corymbosum	Ericaceae	B+, B—, M	Ac, Aq, Alc, E	O	123, 55
Vaccinium myrtillus	Ericaceae	B+	O	O	40
Vaccinium vitis	Ericaceae	B+, B—, Ph, V	O	L, Fr	171, 35, 36
Valeriana dioica	Valerianaceae	B+	O	Fl, L, R	40
Valeriana sambucifolia	Valerianaceae	B+, B—	O	Fl, L, R	40, 171
Veltheimia glauca	Liliaceae	M	Aq	Bu, R	41
Veratrum fimbriatum	Liliaceae	B+, B—	Alc	R	41
Verbascum blattaria	Scrophulariaceae	B+, B—	+, S	L, R, S, St	16
Verbascum nigrum	Scrophulariaceae	M	O	Fl, L, R	40
Verbascum thapsus	Scrophulariaceae	B+, M	Alc, Aq	Fl, L, St	41, 42
Verbena augustifolia	Verbenaceae	B+, B—	+, E	O	16
Verbena erinoides	Verbenaceae	M	Aq	L	120
Verbena hastata	Verbenaceae	B+, B—	E	L, St	16
Verbena urticifolia	Verbenaceae	B+	E	L	16
Verbesina virginica (*Phaethusa virginica*)	Compositae	Y	Aq, —	L	138
Vernonia altissima	Compositae	Y, B+	—, E	L, Fl, S	138, 16
Veronica officinalis	Scrophulariaceae	B+, B—	Ac, E	L, St	40, 55, 10
Verticordia brownii	Myrtaceae	B+	Aq	Fl, L	4

Plant Name	Family	Activity	Type of Extract	Plant Part Tested	Ref's
Verticordia monodelpha	Myrtaceae	B+	Aq	Fl	4
Verticordia plumosa	Myrtaceae	B+	Aq	Fl, L	4
Viburnum alnifolium	Caprifoliaceae	B—	E	O	123
Viburnum opulus	Caprifoliaceae	B+, B—	Aq	Fr, L	120
Viburnum rafinesquianum	Caprifoliaceae	B+, M	Alc, Aq	L	42
Vicia angustifolia	Leguminosae	Y	—	L, St	138
Vicia cracca	Leguminosae	M	Aq	L	120
Viguiera deltoidea	Compositae	B+	EJ	E	71
Vinca minor	Apocynaceae	B+	Aq	L	42
Viola primulifolia	Violaceae	Y	Aq, —	L	138
Viola pubescens	Violaceae	M	Aq	E	42
Viola riviniana	Violaceae	B+	O	R	40
Viola tricolor	Violaceae	B+, M	Aq	L	41
Viorna crispa	Ranunculaceae	B+, B—, Y	Aq, +, —	L	124
Vitis bicolor	Vitaceae	B+, B—	E	O	16
Vitis labrusca	Vitaceae	B+, B—	Aq	Fr, S	120
Vitis vinifera	Vitaceae	B+, B—	Ac	R, St	97, 77, 81
Vitis vulpina	Vitaceae	B+, B—	+, E	L, St	16
		W			
Waldsteinia geoides	Rosaceae	B+, M	Aq	L	41
		X			
Xanthium americanum	Compositae	B+, B—	E, +	L, Fr	16, 115
Xanthium pennsylvanicum	Compositae	B+, B—, F	B, +, E, EJ	E, R, S, Fr, L	16, 71, 115
Xanthosoma sp.	Araceae	B+, B—	+, —	petiole	124
Xolisma fruticosa (*Lyonia fruticosa*)	Ericaceae	Y	Aq	L, St	138
Xyris flexuosa	Xyridaceae	B+	Alc	R	41
		Y			
Yucca angustissima	Liliaceae	B+, B—	Alc	L	41
Yucca baccata	Liliaceae	M	Alc	L	41
		Z			
Zantedeschia aethiopica	Araceae	B+	Aq	Fl	119
Zauschneria latifolia	Onagraceae	B+	EJ	E	71
Zea mays	Gramineae	B+, E—, F, Y	Al, Aq, E	Sl, St, L	8, 165
Zea saccharata	Gramineae	B+	Al, EJ	Fr, Sl	112, 66, 157
Zelkova serrata	Ulmaceae	M	Alc	L	119

Table II. Plants Tested Showing **NO** Activity By Methods Employed

A

Abbevillea fenzliana, Abutilon abicennae, A. theophrasti, Acacia albida, A. spadicigera, Acanthospermum australe, Acer buergerianum, A. carpinifolium, Achillea ptarmica, Achimenes grandiflora, Achras zapota, Acokanthera spectabilis, Actinospermum angustifolium, Adenanthera pavonina, Adiantum capillus-veneris, Adonis vernalis, Aesculus parviflora, A. pavia, Agapanthus hollandii, A. inapertus, A. pendulinus, A. umbellatus, Agave albicans, A. americana, A. angustifolia, A. attenuata, A. brandegei, A. decipiens, A. ferox, A. franceschiana, A. franzosini, A. lisa, A. mescal, A. nudis, A. polyacantha, A. prinolei, A. regeliana, A. salmiana,

A. sartori, A. shawi, A. sisalana, A. tequilana, Ageratum houstonianum, Agrostis nigra, Ailanthus cacodendron-umbraculifera, Albizzia kalkora, A. lebbekoides, Albuca nelsoni, A. setosa, Aleurites fordi, A. moluccana, Alisma plantago-aquatica, Aloe africana, A. arborescens, A. aristata, A. barbadensis, A. brevifolia, A. brunnthaleri, A. cameronii, A. candelabrum, A. commutata, A. davyana, A. distans, A. eru, A. ferox, A. grandidentata, A. humilis, A. marlothi, A. microstigma, A. mitriformis, A. nobilis, A. plicatilis, A. robusta, A. saponaria, A. spinosissima, A. striata, A. sublaevis, A. thorncroftii, A. variegata, A. virens, A. vulgaris, A. zebrina, Alternanthera achyantha, A. versicolor, Althaea officinalis, Alyssum maritimum, Amaranthus hypochondriacus, Amaryllis belladonna, Amelanchier laevis, Amorpha fruticosa, Ampelopsis arborea, Amsonia tabernaemontana, Anamirta cocculus, Ananas comosus, Anchusa azurea, A. capensis, Anemone hepatica, A. virginiana, Anethum graveolens, Anisostichus crucigera, Annona muricata, A. squamosa, Anoda hastata, Antennaria neodioica, Antidesma bunius, Apocynum sibiricum, Aquilegia longissima, Aquilegia vulgaris, Arachis hypogaea, Aralia chinesis, A. hispida, Arbutus andrachne, Ardisia wallichi, Argemone alba, Arisaema stewardsonii, A. triphyllum, Arlanthus cocodendron-umbraculifera, Arnica montana, Artemesia absinthium, Arundinaria tecta, Arundo plini, Asclepias cornutii, A. curassavica, A. incarnata, A. syriaca, Ascyrum stans, Asimina parviflora, Aspidistra lurida, Astelia neocaledonica, Aster acuminatus, A. cordifolius, A. ericoides, A. lateriflorus, A. macrophyllus, A. novi-belgii, A. undulatus, Asystasia coromandeliana, Atriplex patula, A. semibaccata.

B

Bambusa multiplex, Baptisia leucantha, B. psammophila, B. tinctoria, Bauhinia galpini, B. hookeri, B. variegata, Beaucarnea inermis, Bellis perennis, Beloperone guttata, Berberis mitifolia, Berrya quinquelocularis, Betula alba, B. nigra, Bidens vulgata, Billbergia pyramidalis, Blechnum serrulatum, Blighia sapida, Boehmeria cylindrica, B. nivea, Boenninghausenia albiflora, Borago officinalis, Borrichia frutescens, Bougainvillea glabra, Bowiea volubilis, Brachycome iberidifolia, Brassaia actinophylla, Brassica campestris, B. hirta, B. kaber, B. napus, B. nigra, B. pekinensis, Brodiaea uniflora, Brosimum alicastrum, Brunfelsia calycina floribunda, Buddleia americana, B. alternifolia, Bursera bipinnata, B. fagaroides.

C

Cabomba caroliniana, Caesalpinia ferrea, Cakile edentula, Calendula officinalis, C. suffruticosa, Calla palustris, Calliandra surinamensis, Callicarpa affinis, Callistephus chinensis, C. hortensis, Calycanthus floridus, Camellia japonica, Campanula americana, C. medium, Campsis radicans, Canna compacta, Capsella bursa-pastoris, Capsicum annuum, Caragana arborescens, Carex arenaria, Carex caryophyllea, C. digitata, C. gracilis, Carissa arduina, C. grandiflora, Carpinus cordata, C. tschonoski, Carpodiptera ameliae, Carum carvi, Cassia fasciculata, C. marilandica, C. occidentalis, C. uniflora, Casuarina glauca, Catalpa hybrida, Cedrus deodara, Ceiba pentandra, Celosia argentea, Celtis bengeana, C. sinensis, C. tala, Centaurea cyanus, Cephalotaxus harringtonia, C. henryi, Cerocarpus betuloides, Cereus peruvianus, Chamaecrista procumbens, Chelone cuthberti, Chenopodium bonus-henricus, Chimonathus praecox grandiflorus, Chionanthus virgineus, C. retusus, Chlorophytum elatum, Chorisia insignis, C. speciosa, Chrysalidocarpus madagascariensis, Chrysanthemum balsamita tanacetoides, C. majus tanacetoides, Chrysoma pauciflosculosa, Cichorium endiva, Cicuta maculata, Cinnamomum camphora, Circaea lutetiana, Cistus crispus, C. monspeliensis, Citrullus coronata, C. vulgaris, Citrus nobilis, Cladrastis lutea, Claytonia virginica, Cleome spinosa, Clerodendron thomsonae, Clethra alnifolia, Clintonia borealis, Cnidoscolus texanus, Coccothrinax crinita, Cocos nucifera, Coix lacrymajobi, Colchicum autumnale, Coleonema album, Commelina communis, C. longicaulis, Comptonia angustifolium, Conoclinium coelestinum, Convolvulus repens, Coptis groenlandica, Cordia alba, C. myxa, C. obliqua, Cordyline terminalis, Coreopsis coronata, C. lanceolata, Coriandrum sativum, Corylus cornuta, Cosmos bipinnatus, Crescentia totumo, Crotalaria rotundifolia, Crotalaria striata, Croton tiglium, Cryptostegia madagascariensis, Cuphea platycentra, Cycas revoluta, Cyananchum vincetoxicum, Cynoglossum amabile, Cyperus alternifolius, C. strigosus, Cyrilla racemiflora.

D

Dactylis glomerata, Daphne mezereum, Dasylirion durangense, D. simplex, D. wheeleri, Delphinium formosum, D. hybridum, Dentaria laciniata, Dianella tasmanica, Dianthus barbatus, D. caryophyllus, D. chinensis, D. deltoides, Diceranдra linearifolia, Dictyosperma grandiformis, Dieffenbachia picta, Digitalis purpurea, Digitaria sanguinalis, Diodea teres, Dion edule, Dioscorea composita, D. glauca, D. grandulosa, D. macrostachya, D. minutiflora, D. multiflora, D. sansibarensis, Diospyros kaki, D. maritima, Dipsacus fullonum, D. sylvestris, Dolichos lablab, Dombeya dregeana, Dracaena hookeriana latifolia, Duranta repens.

E

Echinacea purpurea, Echinocystis lobata, Echium vulgare, Eleagnus glabra, Enkianthus campanulatus, Epigea repens, Epilobium glandulosum, Epiphyllum trucatum, Equisetum hyemale, Eriocaulon decangulare, Eruca sativa, Eryngium amethystinum, E. aquaticum, Erysimum officinale, Erythrina herbacea, Eschscholtsia californica, Eucalyptus obtusiflora, E. paulistana, Euchlaena perennis, Eucommia ulmoides, Eugenia coronata, Euphorbia cyparissias, E. helioscopia, E. marginata, E. pulcherrima, Euphrasia americana, Evonymus atropurpurea.

F

Ferula communis, Ficus auriculata, F. fulva, F. pumila, Filipendula rubra, Flacourtia indica, Foeniculum dulce, F. vulgare, Forchammeria watsoni, Forestiera rhamnifolia, Fouquieria burragei, F. splendens, Frankenia palmeri, Franklinia alatamaha, Fraxinus americana, F. chinensis, F. oregona, F. pubinervis, Funtumia elastica, Furcraea selloa.

G

Gaillardia aristata, Galium aparine, G. asprellum, G. erectum, Garcia nutans, Gardenia jasminoides, Gasteraloe pethamensis, Gasteria acinacifolia, G. carinata, G. excelsa, G. obscura, G. picta, G. punctata, Gautheria procumbens, Gelsemium sempervirens, Geranium maculatum, Gerardia fasciculata, Geum canadense, G. strictum, Glechoma hedeacea, Gleditsia triancanthos, Glycine max, Gnaphalium uliginosum, Gomphrena globosa, Gossypium hirsutum, Grewia biloba, G. occidentalis, Gypsophila elegans.

H

Habenaria lacera, Halesia diptera, Halodule wrightii, Hamamelis virginiana, Haplopappus divaricatus, Hedeoma pulegioides, Hedera helix, Helianthus tomentosus, H. trachelifolius, Hemigraphis colorata, Heterotheca subaxillaris, Hibiscus aculeatus, H. incanus, H. rosa-sinensis, Hieracium paniculata, H. pilosella, Hyacinthus orientalis, Hydrangea petiolaris, H. radiata, Hydrocotyle americana, Hymenopappus scabioseus, Hypericum cistifolium, H. kalmianum, H. punctatum, Hyptis radiata, Hyssopus offinalis.

I

Idria columnaris, Ilex ambiqua, I. aquifolium, I. cornuta, I. opaca, I. paraguariensis, I. verticillata, I. vomitoria, Illicium parviflorum, Impatiens sultani, Indigofera chinense incarnata, Ipomoea arborescens, I. coccinea, I. sagittata, Iris germanica, I. versicolor, I. virginica, Isoloma bogotense, Iva frutescens, Ixora coccinea, I. macrothyrsa.

J

Jasminum dichotomum, J. multiflorum, Jatropha cinerea, J. cordata, J. hastata, J. manihot, Jeffersonia diphylla, Juncus effusus.

K

Kalanchoë fedtschenkoi, K. flammea, K. verticillata, Kalmia polifolia, Kleinhovia hospita, Kleinia articulata, Kniphofia uvaria, Kochia childsii, K. trichophylla, Koellia albescens, Koelreuteria formosana, Kosteletzskya virginica, Kraunbia floribunda.

L

Lachnanthes tinctoria, Laciniaria chapmanii, Lactuca sativa, Lagerstroemia speciosa, Lamium amplexicaule, L. maculatum, Lantana trifolia, Laportea canadensis, Lathyrus japonicus, L. odoratus, Ledum groenlandicum, Lemna minima, L. minor, Leonotis nepetaefolia, Leonurus cardiaca, Lespedeza cuneata, L. hedysaroides, Levisticum officinale, Ligustrum japonicum, L. compactum, Lilium speciosum, Limonium nashii, Linaria canadensis, L. moroccana, Linum grandiflorum, Lippia citriodora, Liriope spicata, Litchi chinensis, Lithocarpus glaber, Lobelia cardinalis, L. erinus, L. inflata, Lonicera maackii, Loropetalum chinense, Lucuma nervosa, L. salicifolia, Lupinus diffusus, L. hartwegii, Lychnis alba, L. chalcedonica, Lyonia lucida, Lysimachia nummularia, L. obtusifolia, L. punctata, L. quadrifolia, L. vulgaris.

M

Macadamia ternifolia, Magnolia soulangeana, M. virginiana, Mahonia aquifolium, M. trifoliata, Maianthium canadense, Malphigia punicifolia, Malus kaido, M. sieboldi, Malva moschata, Mammillaria bocosana, Mangifera indica, Manihot angustifolia, Manikara bidentata, Markhamia hildebrandti, Marrubium vulgare, Matricaria maritima, M. matricariodes, Melissa officinalis, Mentha arvensis, M. canadensis, M. piperita, Mertensia maritima, Mesadenia sulcata, Mesembryanthemum cordifolium, M. linguiforme, Micranthemum micranthemoides, Mimusops elengi, Mirabilis jalapa, Monotropa hypopithys, Mondo planiscapus leucanthus, Morinda citrifolia, Morus rubra, Musa nana, Myosotis sylvatica, Myrciaria cauliflora, Myrica cerifera, M. rubra, Myriophyllum heterophyllum.

N

Nama corymbosum, Narcissus incomparabilis, N. poetaz, N. poeticus, N. pseudo-narcissus, Nauclea esculenta, N. orientalis, Neillia longiracemosa, Nemesia strumosa, Nemophila insignis, N. menziesii, Nepeta cataria, Nicotiana alata, N. suaveolens, Nigella damascena, Nolina greenei, N. microcarpa, N. palmeri, N. parryi, Noronhia emarginata.

O

Oenothera laciniata, Olea eropaea, Olneya tesota, Oncoba spinosa, Onoclea sensibilis, Onopordon acanthium, Opuntia vulgaris, Origanum majorana, O. vulgare, Ornithogalum thyrsoides, Osmanthus americanus, Osmorhiza claytoni, O. longistylis, Osmunda cimmamomea, O. claytoniana, O. regalis, Oxalis acetosella, O. montana, Oxypolis rigidior, Oxytria crocea.

P

Panax quinquefolium, Pandanus veitchi, Panicum capillare, P. miliaceum, Papaver orientale, P. rhoeas, Parietaria officinalis, Passiflora incarnata, Pastinaca sativa, Paullinia leicoparpa, Peltogyne nitens, Penstemon multiflorus, Pereskia aculeata, Periploca graeca, Petroselinum hortense, Petunia hybrida, Phaseolus lunatus, Philadelphus coronarius, P. henryi, Phillyrea latifolia media, Phlox divaricata, P. drummondii, Phoenix farinifera, P. tomentosa, Phoradendron pachycereus, Phormium tenax, Photinia parvifolia, Phragmites phragmites, Phryma lep-

tostachya, Physalis pubescens, Phytolacca decandra, Picramnia quassiodes, Pimpinella anisum, Pinus palustris, P. taeda, Piptadenia macrocarpa, Piqueria trinervia, Pistacia terebinthus, Pisum sativum, Pittospermum pentandrum, P. tobira, Plantago major, P. rugeli, Plcea tenuifolia, Poa annua, Podocarpus macrophylla, Polygonatum aviculare, P. dumetorum, P. multiflorum, Polygonella croomii, P. macrophylla, Polygonum affinis, P. auberti, P. aviculare, P. bistorotides, P. convolvulus, P. dumetorum, P. exsertum, P. sagittatum, P. scabrum, Populus berolinensis, P. berolinensis rossica, Portulaca grandiflora, Potamogeton fluitans, P. natans, Potentilla anserina, P. intermedia, P. simplex, P. tridentata, Premna odorata, Prenanthes serpentaria, P. trifoliolata, Primula polyantha, Proserpinaca pectinata, Prunella vulgaris, Prunus serralata, P. subhirtella, Psidium guineense, P. littorale, Pteris aquilinum, Pterocarya stenoptera, Pyracantha crenulata, Pyrola elliptica, Pyrostegia ignea, P. venusta, Pyrrhopappus carolinianus, Pyrus angustifolia, P. arbutifolia, P. calleryana, P. floribunda, P. ussuriensis.

Q

Quamoclit pinnata, Q. sloteri, Quercus acutissima, Q. alba, Q. pagoda, Quillaja saponaria.

R

Radermachera fenicus, Ranunculus aquatilis, Rhamnus davurica, Rhodotypos scandens, Rhoeo discolor, Rhus toxicodendron, Ribes manshuricum, Ribes sativum, Rohdea japonica, Rosa alba, R. blanda, R. borbonica, R. cariifolia, R. humilis, R. setigera, Rosmarinus officinalis, Rubus cuneifolius, R. trivialis, Rumex acetosa, R. obtusifolius, R. verticillatus, Ruscus aculeatus.

S

Sabal palmetto, Sabbatia elliottii, S. macrophylla, Saccharum officinarum, Sagittaria lorata, Saintpaulia ionantha, Salicornia europaea, Salix babylonica, Salpiglossis sinuata, Salvia splendens, Sambucus niger, S. racemosa, Sanchezia nobilis, Sanguisorba minor, S. officinalis, Sarracenia purpurea, Sasa veitchi, Sassafras albidum, Satureia hortensis, Scabiosa atropurpurea, Schizanthus wisetonensis, Scilla bifolia, Scindapsus aureus, Scutellaria epilobiifolia, S. laterifolia, Sebastiana ligustrina, Sedum pachyphyllum, Sedum purpureum, Sempervivum tectorum, Senecio glabellus, S. mikanioides, Sesuvium portulacastrum, Setaria macrostachya, S. viridis, Sida rubromarginata, Silene latifolia, Silybum marianum, Simmondsia chinensis, Sinapis alba, Siphonychia erecta, Sisymbrium officinale, Smilax glauca, S. herbacea, S. lanceolata, S. laurifolia, S. officinalis, S. ornata, Solanum dulcamara, S. melongena, Solidago bicolor, S. graminifolia, Sonchus arvensis, S. asper, Sorbus alnifolia, Sorghum vulgare sudanense, Sparganium americanum, Spiraea salicifolia, Spiranthes cernua, Spironema fragrans, Spondias cytherea, Stachys officinalis, S. sieboldi, Stapelia gigantea, Statice elata, Steironema ciliatum, Stellaria graminea, S. media, Stenolobium stans, Stenotaphrum secundatum, Stephania cepharantha, Stranvaesia davidiana, Strelitzia reginae, Strophanthus hispidus, S. sarmentosus, Strychnos spinosa, Suaeda maritima, Swietenia mahagoni, Symplocos paniculata, S. tinctoria, Symphytum asperum, Syringa oblata, Syzygium jambos.

T

Tagetes lucida, Tamarix juniperina, Taxodium ascendens, Tectona grandis, Terminalia arjuna, T. chebula, T. muelleri, Thalassia testudinum, Thalictrum dioicum, Thalia geniculata, Thelesperma hybridum, Thevetia nereifolia, T. peruviana, Thrinax parviflora, Thuja orientalis, Thymus vulgaris, Tilia americana, T. dasystyla, T. euchlora, T. heterophylla, T. platyphyllos, Tillandsia utriculata, Trachymene caerulea, Tradescantia virginiana, Tragopogon porrifolius, T. pratensis, Trichocereus lamprochlorus, Trifolium arvense, T. minus, Trilisa odoratissima, Trillium erectum, Triticum vulgare, Triumfetta polyandra, Trypterygium wilfordi, Tsuga canadensis, Typha angustifolia.

U

Uniola paniculata, Urginea maritima, Urtica gracilis, U. urens, Utricularia inflata.

V

Vaccinium melanocarpum, Valeriana officinalis, Vallisneria americana, Veratrum viride, Verbascum virgatum, Verbena hybrida, Veronica maritima, Veronicastrum virginicum, Viburnum americanum, V. cassinoides, V. kansuense, V. macrocephalum, Vicia cracca, V. sativa, Vigna sinensis, Viguiera tomentosa, Vinca major, V. rosea, Viola cornuta, V. nephrophylla.

W, X, Y, Z

Weigela wagneri, Wisteria sinensis, Xeronemma moorei, Yucca aloifolia, Y. faxoniana, Y. filamentosa, Y. gloriosa, Y. recurvifolia, Y. schidigera, Y. torreyi, Y. whipplei, Zanthoxylum palmeri, Z. simulans, Zebrina pendula, Zinnia elegans, Z. grandiflora, Zisyphus jujuba, Z. mauritiana.

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The Use of Maize by the New Zealand Maoris

The only European vegetable introductions which have been absorbed by the Maoris as standard items are potatoes, squash and maize. The one use of maize developed by the Maoris which has been considered unique is the process of "rotting" or fermenting in water prior to eating. This process is similar to one employed in the Sierra of Ancash in Peru.

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The earliest recorded introduction of maize, *Zea mays* into New Zealand may be dated back to 1772 in two separate accounts of Marion du Fresne's voyage by Roux and Crozet. In both journals, accounts are given of the sowing of maize and other vegetable seeds in the Bay of Islands, Northland. This and subsequent early introductions are referred to by Best in his account of Maori agriculture (1).

Of the many vegetables introduced since the first European settlement, the only kinds which could be described as absorbed by the Maori to become standard items in their gardens were potatoes, squash, and maize. These supplemented the rather short list of cultivated plants used for food (1). With the new varieties of potatoes (*Solanum tuberosum* L.) and squash (probably *Cucurbita pepo* L.) which became available in the 19th and early 20th centuries, the older introductions were discarded by the European populations, but many of these survive to the present, owing to their conservations by the Maoris in rural areas, mainly in the North Island. Whether the earliest introductions have been saved cannot be opined, but the collection of potatoes to be described in a separate study contains many which have not been grown by Europeans within living memory. With maize there is less possibility of the very early types being saved since the Maoris, whose own agricultural crops were in the main vegetatively reproduced, did not adapt readily to grain harvesting as a means of plant perpetuation. However, in a short span of time, the Maori developed his own standards for seed saving and utilization, which together form the subject of this account.

Distribution and General Description

Maize is grown in Maori gardens in the North Island of New Zealand as a summer crop, from latitude 40° S northward. These gardens may be either fenced enclosures in farm fields or they may adjoin houses in small Maori communities. Invariably squash is planted in association to be harvested after maize. It would be difficult to estimate the acreage of such a generally grown family kitchen type of crop, but the greatest concentrations seem to be in the area of Northland, Hawkes Bay, Poverty Bay, and the Bay of Plenty. In the latter two districts, maize is an important agricultural crop, and hybrid maize of U. S. origin is used extensively.

There can be no firm description of Maori maize. Either through the saving of heterogeneous material without rigid selection, and/or the spasmodic introduction of new parental material from agricultural sources, there is considerable variation from place to place and within any one stock. In general Maori stocks

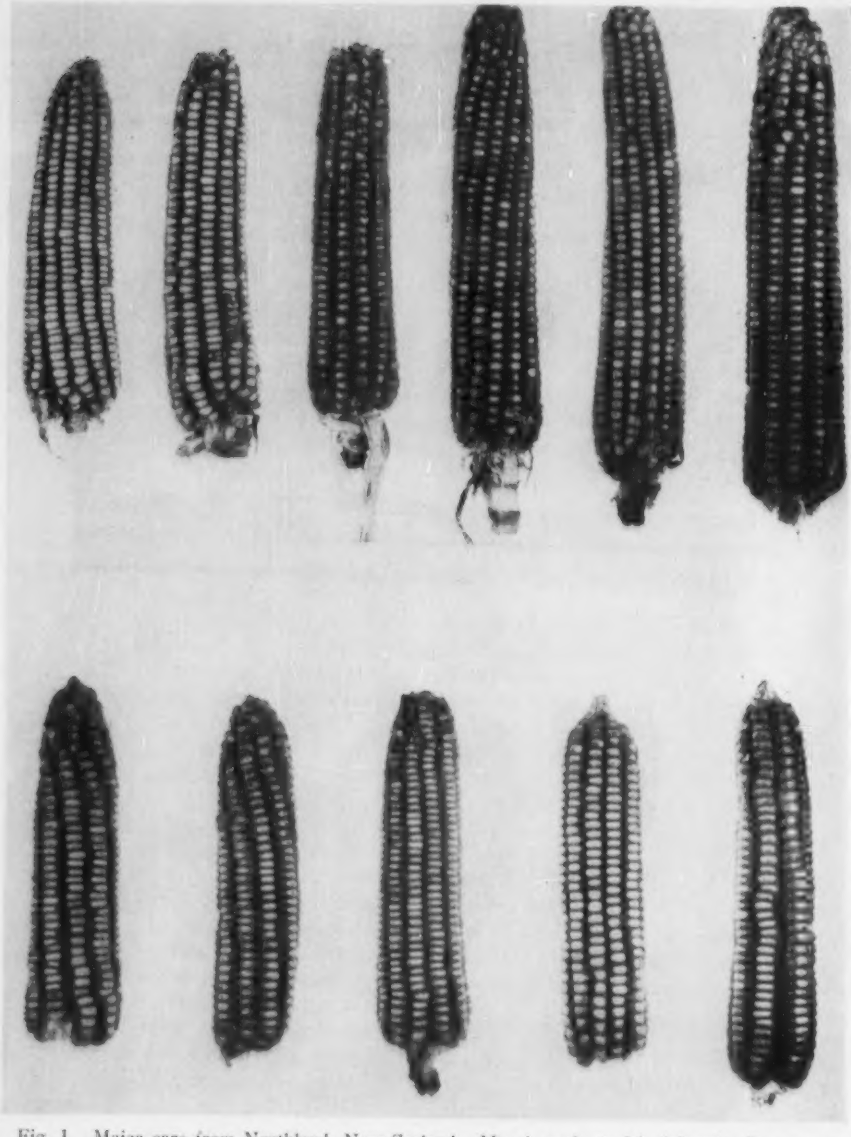

Fig. 1. Maize ears from Northland, New Zealand. Maori seed stock. (above) Representative sample from stock of Mrs. Henare, Motautau. Ear at extreme right 11 inches in length. (below) Sample from stock of Mr. J. Te Whiu, Panguru. Photos: S. A. Rumsey, Pl. Dis. Div. D.S.I.R.

are usually characterized by tall, vigorous, single-stalked plants, and the majority are deep-yellow grained and starchy. However, variations in these characters exist as well as in rows per ear (eight to fourteen), straightness of rows, smoothness and shape of grains, cob color, and maturity. Fig. 1 shows samples from two areas in Northland. The two donors are of the same tribe, but maize selection has been going on separately. They may not have started with the same stock, and certainly in recent times they have had access to different introductions.

Sweet corn has not found particular favor with the Maoris who seem to prefer the starchy maize even for use in the immature stage. The writer has not encountered many families who claim to have kept their own sweet corn seed for any length of time, although all have grown it at one time or another. Other introductions, though, have been accepted, and one is liable to come across unexpected types in out-of-the-way places. A black grained corn similar to the Black Mexican sweet corn is occasionally encountered in the far North. Fig 2. shows some of the recent introductions, including some popcorns which were introduced during World War II, and seed saved since. U. S. hybrid agricultural maizes have been grown recently by Maoris in the Bay of Plenty area. They do not save seed from these partly because they have been advised not to, but mainly because many had tried when hybrids were first introduced.

The vernacular name covering all maize is *kaanga*.

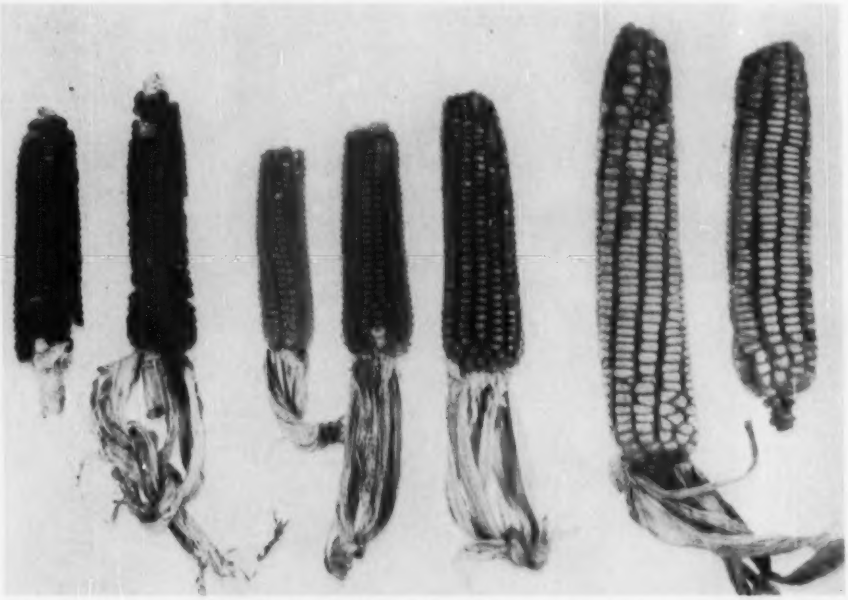

Fig. 2. Maize ears from Northland, New Zealand. Recent introductions. (left) Two ears black-grained, sweet corn type. Note two yellow grains in extreme left cob. (center) Three ears various popcorns. (right) Two cobs white-grained, brought from Egypt after World War II. Photo: S. A. Rumsey.

Seed Saving

The methods of saving seed and the standards for selecting ears are claimed to have been handed down for generations. To substantiate these claims the writer has, on several occasions, been shown books which record family and district histories, farming records, and practices. These books, usually lined school exercise books which may be up to 100 years old are regarded as heirlooms and are written in Maori (English script). Details down to lists of vernacular names for European vegetables are included. It seems that the written language has been a positive contribution which has allowed the expression of the Maori sense of history which could only be handed down by word of mouth in older times.

From these histories, then, as well as by word of the older people, the following cob selection points are generally observed: long cobs, 10″ to 12″; yellow kernels; 12 or more rows per ear; rows straight; grain tight and developed up to the tip, i.e. capped. Cobs displaying this latter character are termed "female" while open-tipped cobs are "male".

At harvest husks are inverted, and the cobs are hung on wooden poles (Fig. 3) for drying. Where grain is removed from cobs selected for seed only, the middle section (one half to two thirds) of the cob is used, the seed on the tip and butt ends being used as fowl feed. Cobs not selected for seed are used for human consumption as described in the next section.

Many of the standards for seed-saving undoubtedly had their origin with the

Fig. 3. Maize tied on pole for drying and for protection from rats during drying. Sacking covering cobs said to camouflage cobs from domestic poultry. Mrs. Henare of Motautau, Northland, in foreground.

missionaries who were responsible for much of the new agricultural development among the Maoris. Maize was an established part of the complement of mission crops in Northland together with wheat, potatoes, and pumpkins (5). The application of gender in classifying cob type could well have been the start of some imaginative folklore of which there are many examples.

The variable stocks of maize have already been referred to. Even with the heterogeneous starting material, it is somewhat surprising that there are few stocks that one could describe as relatively even. The explanation probably lies in the fact that effective isolation from other varieties of maize and sweet corn is not always practiced. Thus, there is an irregular and uncontrolled infusion of new material which often works against the aims of selection. The cause of resulting variability, especially in maturity, is not appreciated by the Maori, whose desire for a uniform-harvesting crop is similar to that of most corn breeders!

There seem to be no varietal names for maize, and the writer questioned an old Maori lady on this. The fact that potato varieties are named in a similar way to the traditional food, the kumara (*Ipomoea batatas* Poir), seemed to indicate that the maize might be of much more recent adaptation, i.e. that the early introductions were not perpetuated. The old lady's reply was that it was useless naming something that altered from year to year. This statement has many of the implications stated previously.

Fig. 4. Hangi or earth-oven, Northland. No'e maize growing in background. Photo: National Publicity Studios, N. Z. Govt.

Utilization

According to accounts of early introduction, the Maoris attempted to eat maize raw, and they carried dried grains when traveling. However, they soon put the crop to many uses, by adopting European cooking procedures, adapting it to their own methods, and inventing new uses. European methods of cooking sweet corn by boiling and frying are probably most often used now. The stage of maturity for these purposes is perhaps later than that considered ideal in sweet corn. The corn cob, because of its stability under most cooking conditions, is well suited to the earth-oven preparation with meat and other vegetables (Fig. 4) and is generally considered best for this when quite mature.

The popping of maize by throwing grain into embers and by the use of heated metal pots is a use which has been more popularized by the introduction of the small-grained popcorns.

The use that has been considered unique, however, and one that is repulsive to Europeans who have been in contact with it is the process which involves the "rotting" or fermenting of maize in water prior to eating. References are often made to this in early New Zealand literature. The process is termed *kaanga-kopuwai* (= maize soaked in water) in Northland and *kaanga-pirau* (= rotten corn) and *kaanga-wai* (= water corn) among the Maoris of Central North Island and the Bay of Plenty.

It was noted with considerable surprise that a similar process called *tocos* used in the Sierra of Ancash in Peru was recorded by Rick and Anderson (7), and thought by them to be unknown outside of Ancash. For comparison a brief description of the Maori process follows: mature whole cobs are placed unhusked in a jute sack which often contains stones for added weight. The full sacks are secured and then submerged in water. A piece of wire attached to the end of the bag and to some disguised marking spot, e.g. shrub branch or log, is the sole means of finding and recovering the bag. The bag must be totally submerged, and both running water of streams and still, almost stagnant water ponds, run-offs from pastures, etc., are used (Fig. 5). Some Maoris say that the latter is preferable. The time required for the process is three months for the mature hard-grained cobs that are generally used, and the corn is ready for use when soft. It is said that the corn will stay fit for eating indefinitely if left in the water. Some informants stated that when it is desired to keep the *kaanga-kopuwai* submerged for long

Fig. 5. The processing of maize by soaking. Mr. J. Te Whiu recovering sack of soaked maize from run-off pool in pasture, Panguru, Northland.

periods it is the sack that is the problem, and they tie bundles of *mange mange* (*Lygodium articulatum*) around the sack to preserve it. *Mange mange* is a fern with long and wiry stems commonly found in the northern forests.

The maize, after six weeks of soaking, has a fresh appearance (Fig. 6) but already has the smell which has been graphically described by Rick and Anderson. At twelve weeks the husks are yellow and soft, the grain full, but very soft, and often slimy to the touch. The smell, if anything, intensifies. Fermenting the grains without cob is said to decrease the intensity of the odor but results in an inferior flavor.

Preparation is again similar to that practiced by the Ancash Indians. The kernels are scraped off the cob, the pericarp sometimes being removed; after mincing or pulverizing it is ready to boil with water to form a sort of gruel which is eaten hot with sugar and milk or cream. An alternative preparation not often encountered is frying of the fermented grains with salt and animal fat. Dieffenbach (3) states that grains were pounded and baked into cakes, but no survival of this method has been found.

The maize used in this process is in contrast to the white maize used by the Ancash Indians, but all new introductions are apparently tried. Sweet corn goes "rotten" and the general consensus of opinion is that "nothing is as good as the old Maori maize".

Young maize used for soaking is said by some to have an upsetting effect on the stomach. Early missionaries and health officers have, for health reasons, discouraged the Maoris from using this processed maize but in most rural areas it has persisted to the present. Dieffenbach (3) said in an account of his travels in New Zealand in 1841 " . . . . . and the missionaries encouraged them to exchange their former unwholesome food of decayed maize and potatoes for bread", claiming that he had known gastric fevers to be caused "exclusively" by this food. The Maoris claim that it is health-giving and many of the older people attribute their age to this maize in their diet. The comparison drawn by the Maoris between their corn process, during which flies do not amass round the product, and some of the older English culinary habits such as the hanging of undressed game for weeks prior to cooking, occasions much amusement.

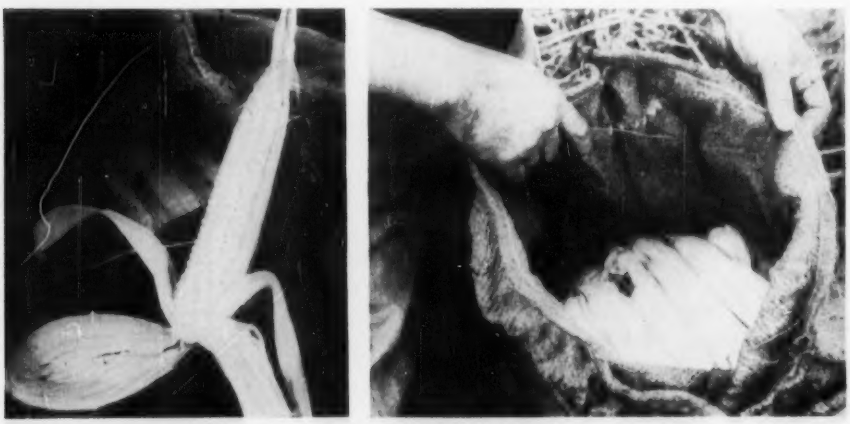

Fig. 6. Sack opened for inspection of maize soaked six weeks.

The Origin of the Maize Soaking Method in New Zealand

With the coincidence of the fermentation method in the Ancash, Peru, and New Zealand, it is reasonable to suggest that the process is older in Peru, which is so much closer to the generally accepted center of origin of maize and has well known connections with the plant in archaeological findings. It may be further suggested that the process was directly transferred from Peru post-1769. The great activity in Pacific whaling in the early 1800's might have been responsible for this transfer (and further unrecorded introductions of maize seed). Many European sailors settled in New Zealand after voyages, and Maoris themselves could have been responsible, since Polynesians were often signed on whaling expeditions which encompassed the Pacific. Rick and Anderson (7) state there is little evidence of *tocos* outside the Sierra of Ancash, so that a voyager would have to land in Peru, probably at Callao, make his way to Ancash, then back to New Zealand to make his discovery known. No documentation of such a voyage has yet been found in the available maritime sources studied so far, but this does not deny its occurrence.

Indirect introduction from Peru through the Pacific Islands may be a further possibility. Buck (2) in summarizing the voyages of early Pacific explorers shows the many connections of Peru with Polynesia. Although no record of the process can be obtained in the Islands, the likelihood of its introduction and subsequent transfer to New Zealand cannot be discounted completely. Dieffenbach's New Zealand observations made between 1839-1841 establish that the transfer of the method took place earlier, since it was at that time a widely used means of utilization among North Island tribes. Further support for the idea of direct transference of this soaking method of corn use lies in the fact that there is a parallel use of the method in potatoes. Rick and Anderson mention the use of a certain potato variety in a similar process in Ancash called *tocos de papa*. In New Zealand, it is called *porutu* or *ngaio* in the north and *kotero* among the Maoris of the central part of the North Island, and the varieties used are the older "Maori kinds". Tubers are soaked whole in running water for three weeks approximately, until soft. The resultant product is cooked similarly to maize, producing a strong-smelling, gruel-like food.

Potatoes are said to have been introduced into New Zealand by De Surville in 1769 (1), and thus ante-dated first maize introduction by a few years only. There seems little doubt that the advent of potatoes had a great influence on the food habits of the Maori, who soon adopted the crop as his own. The introduction of the fermenting process may have been instrumental in the possibly later adoption of maize as a crop. Many Maori informants claim the potato to be a plant originally introduced by the Maori, but this claim is seldom made for maize.

The alternative possibility is that this utilization method originated in New Zealand by independent invention. That the Maoris formulated this process based on treatments of some of their older traditional foods might have some substantiation.

Two native tree fruits gathered for food were treated in similar ways to produce different products. The hinau (*Elaeocarpus dentatus*) fruits were steeped in running water for several days after which a fine olive-colored meal was obtained and kneaded into cakes. The karaka (*Corynocarpus laevigatus*) fruits were steeped in water after cooking to rid them of a poisonous bitter glucoside after which they were dried and the seeds eaten as nuts. Descriptions of these processes have been published (8) (9). Sea foods were also fresh water treated; pipis (*Amphidesma australe*) and crayfish (*Jasus lalandii*)

were two such. In fact, they are still used in this fashion in many parts of the North Island.

This summary of some of the applications of soaking of traditional foods shows that the separate Maori invention of maize and potato processes is not impossible. In the case of independent invention, the acceptance of the new process (or the new application of an old process) would be immediate—the evolving of a process long. An introduced method of preparation gives an immediate process, but it is probably accompanied by a more reluctant and therefore gradual acceptance.

In Africa, where maize has an interesting and longer history (4) than in New Zealand, many more methods of preparation by the natives are extant. These have been summarized by Miracle (6). Processes of which soaking or fermentation are a part include the brewing of maize beer from sprouted then dried grains, and the preparation of a mash from kernels soaked in water and wood ash. The direct parallel of the South American *tocos* method which exists in New Zealand has not been recorded elsewhere.

Conclusion

At the first contacts of Maori and European, one of the first exchanges involved food and food plants. The Maoris received food plants from the European which he desired to be propagated for his use. The Maori took those which he preferred, and in a way, retreated with them to "re-domesticate" them under his own environment and to his requirements. With success, he cultivated and perpetuated such a crop as potato which was similar to his older crop the kumara or sweet potato, but with maize he seemed to be only progressing toward a seed culture with his own standards of selection. His adaptations of it to his taste, whether by his own invention or by introduction, became stabilized to become a near-essential in his diet. It may be idle to speculate that the further inroads of European values into Maori life have limited the traditionalizing of the uses and culture of the early food plant introductions.

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The Domestic Tung Industry. I.
Production and Improvement of the Tung Tree.

In 1904 the American Consul General at Hankow, China sent seed of tung (Aleurites fordii) to the U. S. Dept. of Agriculture at Chico, California. One tree planted near Tallahassee, Florida in 1907, produced a crop of fruit in 1913, from which the first 2.2 gallons of American tung oil were extracted. By 1930, nearly 8000 acres of tung orchard had been planted in Florida, and extensive plantings were made in Mississippi and Louisiana. By 1938 there were approximately 200,000 acres of tung orchards in the southeastern United States. Today the tung industry is hard-pressed to meet competition from substitutes and from importations. American tung growers are striving to get their industry on a sound economic basis by lowering their cost of production and widening the market for tung oil.

GEORGE F. POTTER[1]

Origin of the Domestic Tung Industry

The tung tree, *Aleurites fordii* Hemsl., is native to central and western China. Its fruits yield a superior drying oil, which the Chinese have used for hundreds of years for making lacquers and varnishes, for waterproofing, and for other purposes. In the late 1800's, American paint and varnish manufacturers began to import increasing quantities of tung oil from China. Believing that the tree would be climatically adapted to some of the warmer sections of the continental United States, L. S. Wilcox, Consul General at Hankow, China, sent seed to the Section of Plant Exploration and Introduction, U. S. Department of Agriculture, in 1904. Seedlings were grown at Chico, Calif., and sent to cooperators in various parts of the United States. Several of the trees planted in the southeastern states, grew satisfactorily. One tree planted in 1907 near Tallahassee, Fla., by W. H. Raynes, produced a crop of fruit in 1913, from which officials of the American Paint, Varnish, and Lacquer Association, Inc., extracted the first 2.2 gallons of American tung oil (*22*).

Interest in this new exotic tree grew by leaps and bounds. The American Tung Oil Corporation, organized largely by manufacturers of paints and varnishes, planted a trial orchard near Paradise, Fla., and plantings by other private interests increased steadily. By 1930, nearly 8000 acres of tung orchard had been planted in Florida, and extensive plantings were being made on the cutover pine lands of Mississippi and Louisiana. By 1938 there were roughly 200,000 acres of tung orchard in the southeastern United States, mostly in Mississippi, Florida, and Louisiana but to a lesser extent in Alabama, Georgia, and Texas. Planting since 1938 has been on a moderate scale. A good general review of the development of the tung industry was published by Blackmon (1) in 1943.

The Tung Tree

The genus *Aleurites* belongs to the *Euphorbiaceae*, or Spurge, family. Five species of *Aleurites* are known: *fordii, montana, cordata, trisperma,* and *moluccana*. The tung oil of commerce comes largely from *A. fordii* (Fig. 1) but partly from *A. montana,* which grows only in tropical areas such as southern China, Burma, and British Central Africa. The oils of *A. cordata* and *A. trisperma* con-

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1. Portion of a tung tree showing heart-shaped leaves and fruit about to mature. Photo by Crops Research Division, ARS, USDA.

tain less eleostearic acid, the constituent that gives tung oil its superior quality, and the oil of *A. moluccana* contains none. The tung industry of the southeastern United States is based exclusively on *A. fordii*. *A. montana* can be grown in central and southern Florida but not on a commercial scale.

Trees of *Aleurites fordii* grow rapidly and may attain a height and branch spread of 25 feet in 7 to 10 years. Ultimately, they may reach a height and spread of 40 feet. The leaves are dark green, usually 3 to 6 inches in diameter on mature trees, broadly ovate and sometimes lobed. Clusters of whitish, rose-throated flowers are produced in early spring from terminal buds of shoots of the previous season. The tung tree is monoecious, producing staminate and pistillate flowers in the same inflorescence; ordinarily, staminate flowers greatly outnumber the pistillate. Normally, all new shoots arise from growing points within the same terminal buds as the flowers. The tree is deciduous, and its habit of branching only at the tips of shoots of the previous season gives it a unique appearance, especially during the dormant season.

The fruits of the tung tree vary considerably but generally are oblate-spheroid and about the size of small apples. As they approach maturity, the color may range from green to a deep purple; frequently, there is a red blush on a greenish-yellow ground. The fruit consists of several single-seeded carpels, usually 4 or 5. Each carpel has an outer boat-shaped hull, of pulpy texture while the fruit is on the tree, but which dries to a subwoody fibrous texture after the fruit drops to the ground. The carpel and inner hull separate readily from the outer hull.

The development of the tung fruit takes place in two distinct stages. At the time of full bloom, the ovary is about the size of a pea. The structural units of hull and seed develop rapidly and attain full size by about the first of July (12). Increase in size of the fruit takes place during the period of shoot growth of the tree (10). When growth in size of the fruit ceases, the outer epidermis of the inner integument of the seed coat hardens and forms the shell of the seed. At that time, embryo and endosperm are of microscopic size, and the remainder of the seed is filled with nucellar tissue. During the second stage of development, July to October, growth of the embryo and development of the endosperm take place at the expense of nucellar tissue and the inner integument of the seed coat. The oil is contained largely in the endosperm. Its accumulation begins gradually about July 15, proceeds very rapidly during late August and September, and then at a decreasing rate as the fruits mature. The mature kernel (endosperm and embryo) contains about 65% oil, dry weight basis (29).

Ecology of the Tung Tree

Rather exacting climatic requirements limit tung culture in the United States to a belt about 50 to 75 miles wide, extending from southeastern Texas eastward along the Gulf of Mexico to northern Florida and southern Georgia. The tree requires a long, hot summer with abundant moisture, yet it needs a period of 350 to 400

hours in winter when the temperature is 45° F. or lower. Tung differs from the peach and other fruits in that it will set a good crop even when showing symptoms of insufficient chilling such as uneven blossoming over an extended period. Nevertheless, warm winters limit its southern range. The tree is susceptible to cold injury when in active growth and does not withstand temperatures much below 8° to 10° F. when fully dormant. Low winter temperatures limit its northern range.

Many of the early tung orchards were planted on unsuitable soils. Finding that tung did not thrive on excessively drained, infertile sands, Florida growers asserted that tung does best on "heavy" (fine-textured) soils. Mississippi growers, acting on this advice and having a totally different conception of what the term "heavy" soil means, planted on impervious clays. After studying tung orchards on many diversified soils, Drosdoff (4) stated that good drainage and aeration are the most important requisites of a good tung soil. Although the soil cannot be waterlogged, it must be capable of supplying liberal amounts of moisture and nutrients to the tree. A sandy surface soil underlain with a deep, friable, sandy-clay subsoil, which has good internal drainage and which the tung roots can penetrate deeply, is most suitable. Tung trees do best if the sandy surface layer is rather shallow, 12 to 24 inches. If the clay is several feet below the surface, the trees tend to develop slowly but may eventually make vigorous growth and produce well. Nevertheless, tung can be grown successfully on rather deep sandy soils if given special culture and fertilization (19).

Improvement of the Tung Tree

Nearly all tung trees in commercial orchards are seedlings, and during the period of rapid expansion of the domestic industry, little attention was paid to the source of the seed. Consequently, trees in all of the old commercial orchards vary widely in size, habit of growth, productivity, and character of fruit produced. In 1938, U. S. Department of Agriculture personnel began an extensive line-selection project (23). Several hundred outstanding "mother" trees were selected, and seedling progenies of each tree were screened in the orchard. A few trees of the most promising selections were also propagated by budding. Under orchard conditions, tung is probably largely but not wholly self-pollinated. Possibly 5 to 10 percent of cross-pollination occurs. If so, it would be expected on the basis of random chance that cross-fertilization would occur often enough to make most tung trees heterozygous, but that occasionally self-fertilization might occur for several successive generations and a fairly homozygous tree would result. Observation of the progenies of more than 500 mother trees supported these hypotheses. The individual trees of most progenies were diverse, and in a few instances, the seedlings were uniformly poor. In a very few instances, they were rather uniformly good in tree type, productivity, and oil content of the fruit.

Growers visiting the experimental plots became enthusiastic when they saw the uniformly highly productive progenies. Since the work was cooperative, all trees in the experimental plots were the property of cooperating private growers, who began to use and to distribute seed of promising progenies, even before they were officially released. The U. S. Department of Agriculture assumed no responsibility for this practice but offered no objections, because it was obvious that the growers' only alternative was to plant untested seed from their own trees. Ultimately, five varieties of tung were officially released (24):

Folsom. A low-heading variety of high productivity. The fruits are large, mature late, turn purplish as they ap-

proach maturity, and contain about 21% oil. This variety has a high degree of resistance to low temperatures in the fall, a valuable characteristic because the embryonic blossom buds for the next year's crop are sometimes killed at that time of year.

Gahl. A low-heading, productive variety that bears large fruit with an oil content of 20% or slightly more. This variety matures early and has proved somewhat resistant to cold in the fall.

Isabel. (Fig. 2) A very popular, low-heading variety of high productivity. It bears large fruits, which mature early and contain about 22% oil.

La Crosse. A high-heading variety of exceptional productivity. The fruits are small, mature late in the season, and tend to break into segments if not harvested promptly, but have an oil content of 21 to 22%. The variety is popular with many growers, especially those who dislike to cultivate low-heading trees.

Lampton. A very low-heading variety that has outyielded all others. It bears large, early-maturing fruits having an oil content of about 22%. If the trees are overloaded, the oil content may be considerably lower.

When it was found that some seedling progenies are sufficiently uniform for commercial planting, the question arose as to the relative merits of seedling and budded trees. After making a statistical study of the fruit of seedling and budded progenies of each of five mother trees, Lagasse et al. (11) reported that in most instances seedlings were more variable than budded trees in weight per fruit, weight of each kernel, percentage kernel in the fruit, and percentage oil in the kernel. In experiments begun in 1946, Merrill et al. (14) compared growth, yield, and oil content of fruit of seedling and budded progenies of each of eight of the best mother trees then known. The cumulative yield of the seedlings for the period 1947-52 was much higher than that of the budded trees. Budded trees of certain mothers made a much better showing than those of others, but in no case did the budded trees outyield the seedlings.

As of 1958, seedling trees of the selected varieties are planted almost exclusively for commercial oil production. The 'Isabel' (Fig. 2) is probably the most popular, but each variety has its specific advantages and disadvantages. Hence, it is inadvisable for growers to plant only one variety. A grower may prefer 'Isabel' to 'Gahl' and 'Folsom', but in a year following a severe fall freeze, he might get crops on 'Gahl' and 'Folsom' but none on 'Isabel'. Since none of the selected mothers is wholly homozygous, planting budded trees for seed production is recommended.

Cultural Practices in the Tung Orchard

Most tung orchards are planted on the contour, and in a contour planting, distances between rows are never uniform. Planting distances vary widely, and in most of the older orchards, the trees are 20 or 25 feet apart in rows that average 35 or more feet apart. Although the tung tree ultimately grows to such a large size that 45 or 50 trees completely cover an acre of land, returns per acre are low for several years in orchards having only 50 to 70 trees per acre. Closer planting, for example, 10 feet apart in rows 30 feet apart, increases early returns without affecting later yields appreciably. Since contour-planted orchards are seldom cross-cultivated, growth of grass and weeds in the row presents a serious problem if the trees are 20 or more feet apart in the row. The branches of tung trees planted 10 feet apart in the row interlace after 2 or 3 years; the dense shade prevents growth of competing vegetation along the row and greatly reduces the cultivation required.

The tung tree is exceedingly sensitive to competing vegetation. When trial

2. These uniform 1-year-old seedling tung trees were obtained by planting seed from budded trees of the 'Isabel' variety and transplanting only low-heading trees from the nursery. Photo by Crops Research Division, ARS, USDA.

plantings at Ocala, Fla., failed to make satisfactory growth during several seasons, Hamilton and Drosdoff (9) set up an experiment in 1945 to determine the reason. Since the soil was coarse-textured, it was thought that irrigation might be necessary for satisfactory growth. Irrigation did improve growth about 80%, but simply hoeing out the grass left close to the trees in cultivating with a tractor-drawn disk improved it over 400%. The late Robert M. Salter, then Chief of the Bureau of Plant Industry, testified that he had never seen such remarkable response to cultivation. Almost identical results were obtained in experiments on fine-textured soils (13, 21). The depressing effect of grasses on tung tree growth must be due in part to competition for moisture and nutrients but has never been fully accounted for.

Under the best soil management programs for tung orchards, leguminous cover crops (Fig. 3) are grown annually (24). Winter cover crops such as the reseeding varieties of crimson clover are most popular. Most growers produce beef as a companion enterprise with tung, and clover affords some grazing before it is turned under. Cultivation of the orchard starts in May as soon as the clover seed is mature, and many growers disk their orchards about twice a year (24). Others follow the first disking with two or more cultivations with the spring-tooth harrow, a more rapid and less expensive operation than disking.

Nutrition of Tung

The soils of the coastal plain of the southeastern United States where tung is

grown are relatively infertile. To avoid excessive production costs, American tung growers must get good yields. Rather liberal fertilization is required to effect the desired vigorous growth and high production. The nutritional requirements of the tung tree have been studied in controlled sand cultures and in extensive field experiments. Analyses of samples of leaf blades taken from the middle of shoots of modal length in late July or early August have been very helpful in interpreting experimental results (3).

The tung tree is very responsive to changes in nutrition and proved to be an excellent subject for the study of basic principles of plant nutrition. Using leaf composition as a criterion of the nutritive status of trees grown in sand culture, Shear et al. (31) found that responses to changes in concentration of elements in the nutrient solution are often complex. Increasing the concentration of one element may not only affect uptake and accumulation of that element in the leaves and also have a direct effect upon the uptake of another, but its effects on the second element may depend on the concentration of still other elements. The study of many such complex interactions lead to the concept of nutrient-element balance, which is believed to have wide application in plant nutrition.

Sitton (32, 33) conducted extensive factorial field experiments in Louisiana and western Mississippi with both bear-

3. This summer cover crop of alyceclover was turned under along the tree rows to prevent competition for moisture during the dry fall months and to facilitate the harvest. Photo by Crops Research Division, ARS, USDA.

ing and nonbearing tung trees. He found that nitrogen tends to increase vegetative growth of tung trees but may check growth of young trees if applied in excess. Nitrogen applied to mature trees tends to increase the number of new shoots arising from each terminal of the previous year and, hence, the number of terminal buds in which flowers are borne. It also increases the number of pistillate flower buds initiated in each terminal bud. The net result of these two responses is a greatly increased yield. Nitrogen may increase the proportion of the oil-bearing kernel relative to shell and hull in the whole fruit. On the other hand, it considerly reduces the percentage of oil in the kernel, and percentage oil on the whole fruit basis is almost always reduced. Results similar to Sitton's were obtained by Merrill et al. (15) in eastern Mississippi and by Neff et al. (20) in northwestern Florida.

Ammonia, in either anhydrous or aqueous form, is the cheapest source of nitrogen and is widely used in tung orchards. In sand culture, tung trees have made better growth with nitrate than with ammoniacal nitrogen, but the two have been found about equally effective in experiments in the orchard. On the basis of a great many analyses of leaf samples from experimental plots and from commercial orchards, best growth and yield in mature trees appear to be associated with 2 to 2.5 percentage units of nitrogen in the leaves. Growth and production of trees having 2% or less of nitrogen in the leaves tend to be below optimum, and the leaves are rather light or yellowish green in color. As a rule, no response would be anticipated from applying levels of nitrogen that increase leaf nitrogen above 2.5% (7).

Phosphorus is especially low in the soils of the western part of the Tung Belt, but symptoms characteristic of phosphorus deficiency, which have been produced in sand cultures, have never been observed in the field. In order to obtain satisfactory growth of leguminous cover crops, growers are obliged to apply phosphorus. The recommendations of the soil-testing laboratories of the state agricultural colleges may determine the level used. Part of the phosphorus applied to the cover crop will be used directly by the trees, and more will be returned to the soil when the cover crop is turned under. The level of phosphorus needed to produce a good cover crop has always been found adequate for the trees. Ultimately, the trees will shade the ground to such an extent that cover crops can no longer be grown. Nevertheless, the same level of soil phosphorus should continue to be maintained. In the western part of the Tung Belt, however, newly planted tung trees respond to liberal applications of phosphorus. Leaves of healthy, vigorous tung trees usually contain .12 to .22% phosphorus (7).

The potassium content of all soils of the Tung Belt is low, and that of some soils in the eastern part of the Tung Belt is extremely low. The hull of the tung fruit is rich in potassium; as a rule, about 40 pounds of K_2O is removed from the orchard in each ton of whole fruit. When yields of two to three tons per acre are produced by using generous levels of nitrogen, the demand for potassium exceeds the supplying power of any soil of the Tung Belt. Failure to "balance" the fertilizer with an adequate amount of potassium quickly leads to deficiency symptoms of marginal and interveinal chlorosis and necrosis of the leaves. Premature defoliation occurs; the fruits persist on the tree and at harvest have very low oil content. The application of potassium increases both the percentage of kernel in the fruit and percentage of oil in the kernel. In some experiments, a high degree of correlation is found between percentage potassium in the leaf and percentage oil in the fruit.[a] Trees deficient

[a] Data in files of U. S. Field Laboratory for Tung Investigations, Bogalusa, La.

in potassium are exceptionally susceptible to cold injury. As a rule, potassium does not promote growth and yield of tung as much as nitrogen, but in orchards on some soils of the eastern part of the Tung Belt, a marked interaction of nitrogen with potassium on yield has been observed; good yields were obtained only when both elements were supplied in proper proportion (20). Leaves of healthy tung trees that produce fruit of good oil content generally contain at least .70% potassium. From an economic standpoint, it is seldom feasible to maintain more than 1.00% potassium in the leaves of bearing tung trees (7).

All soils of the Tung Belt are rather acid and low in exchangeable calcium. Trees making rather satisfactory growth vary widely in levels of leaf calcium, which may range from 1.00 to 2.50% (7). There is some evidence that oxalic acid is formed as a by-product of the reduction of nitrates, and calcium uptake is related to the formation of oxalic acid and its precipitation as calcium oxalate. Hence, the calcium requirement of trees that receive nitrogen as ammonia is relatively low (8). In some of the coarse-textured soils of the eastern Tung Belt, calcium applied as gypsum has effected substantial increases in yield (19). Thus far, calcium has played a less important role in the nutrition of trees on the fine-textured soils, but there is a general decline in leaf calcium in nearly all tung orchards, and it is possible that trees on these soils may eventually require a calcium application.

Trees on coarse-textured soils frequently require both calcium and magnesium. Although symptoms of calcium deficiency have been observed only in sand culture and never in the orchard, magnesium-deficiency symptoms frequently are widespread in orchards on coarse-textured soils. Magnesium - deficiency symptoms are so similar to those of potassium deficiency that often it is not possible to differentiate them, excepting by chemical test (6). Magnesium deficiency, like potassium deficiency, causes early defoliation while the fruits persist on the tree. Magnesium deficiency also tends to lower the oil content of the tung fruit but less than potassium deficiency. As a rule, it is difficult to correct magnesium deficiency with slowly available forms of magnesium such as dolomite; Epsom salt or other soluble forms of magnesium are required and, even then, recovery is slow. However, dolomite applied to tung trees at or before planting has effectively reduced leaf scorch and increased growth and oil content of the fruit (19). A leaf content of .25 to .40% magnesium is considered satisfactory for mature trees (7).

Since many tung orchards were planted on coarse-textured soils excessively leached by heavy rains, it was not surprising that the use of "minor" or "trace" elements was soon found necessary. Zinc deficiency was the first minor element deficiency to be recognized and corrected. Extensive plantings in the area near Gainesville, Fla., were affected by a disorder which caused the leaves to malform and turn yellowish-bronze and the growth of the trees to be weak and unsymmetrical. The trouble was so serious as to threaten the existence of the industry. Fortunately, the problem was solved by Mowry and Camp (17), who showed that the symptoms can usually be corrected by applying zinc sulphate to the soil. In some instances, however, the zinc-fixing capacity of the soil is so great that zinc sulphate in solution has to be sprayed on the leaves at frequent intervals.

At first it was thought that zinc deficiency would be a serious problem only on coarse-textured soils of Alabama and Florida, but it has been found that orchards on the fine-textured soils of the western part of the Tung Belt may also require zinc. The deficiency is especially likely to occur in trees planted on old, cropped land as compared with virgin soil. Zinc is an expensive element which grow-

ers cannot afford to include in their fertilizer mixtures unless it is really needed. On the other hand, it is unwise to wait until visible symptoms of zinc deficiency occur in the orchard. Analysis of representative leaf samples is very helpful; it enables the grower to know when the zinc supply of his trees is approaching a critical level. A leaf content of 25 to 35 ppm. is considered the lowest safe limit for mature trees (*7*). Zinc does not move downward rapidly in most soils. If applied on the surface, it may not become available to newly planted tung trees during their first year in the orchard. Incorporating the zinc in the soil before planting or dusting it around the sides of the planting hole effects adequate absorption even when low levels of zinc are used (*18*). Although expensive, zinc is worth its cost if an actual deficiency exists.

Manganese deficiency of tung is characterized by an interveinal chlorosis which appears in early summer and tends to disappear later in the growing season. Affected leaves are usually small (*27*). It does not reduce yield or oil content of the fruit appreciably; therefore, growers seldom bother to apply manganese sulphate to correct it. The deficiency is known only in north central Florida, where soils are so deficient in manganese that tung leaves often contain less than 50 ppm. of that element. In northwestern Florida and in other parts of the Tung Belt, tung leaves contain 1000 ppm. or more of manganese, and the deficiency is unknown (*7*).

Deficiency of copper, like that of manganese, occurs only in tung trees growing on certain soils of peninsular Florida. Leaves of affected trees are small and chlorotic and exhibit a characteristic "cupping" caused by the margins curling upward. When the deficiency is severe, terminal leaves drop from the shoots, which then die back. The margin between the copper content of leaves exhibiting deficiency symptoms and healthy leaves is small. Leaves of affected trees generally contain 3 ppm. or less, but symptoms are not observed if the leaves contain 4 ppm. or more (*2*). The deficiency can be corrected by soil applications of copper sulphate. Fortunately, very little tung has been planted on copper-deficient soils.

The boron requirement of the tung tree evidently is very low; deficiency symptoms can be produced in sand culture only by completely omitting boron from the nutrient solution, and they have never been positively identified in the field. Nevertheless, many growers have applied boron, usually with harmful results. In an experiment with tung trees on Red Bay soil in eastern Mississippi, Merrill et al. (*16*) applied boron over a period of 13 years at the maximum safe level, namely, that which produced a very slight tip burn of some of the leaves. The boron increased the percentage of potassium in the leaves but did not increase yield or oil content of the fruit.

Iron deficiency is sometimes troublesome when tung is grown in sand culture but has never been a problem in the orchard.

Fertilizer Applications

Phosphorus is usually applied at the time and in the amounts needed for the leguminous cover crop. If feasible from a farm-management standpoint, a part of the potassium may also be applied to the cover crop. However, it is necessary to adjust the level of potassium to the crop on the trees. Thus, a supplemental application of potassium, involving an additional operation, is required if the trees set a heavy crop.

The blossom buds of tung, like those of many other fruit and nut trees, are formed the summer previous to that in which they open. If the tree is bearing heavily, it tends to initiate relatively few blossom primordia, and its crop is small in the succeeding year. Conversely, in a year of

light crop, it initiates blossom primordia excessively. Thus, tung has a pronounced 2-year cycle of "alternate bearing", and fertilizing liberally with nitrogen every year tends to aggravate this tendency (26). Fertilizing lightly with nitrogen in the year of light crop and heavily in the year of heavy tends to overcome the biennial-bearing cycle to some extent.

The necessity for adjusting the level of fertilizer to the crop carried by the trees makes it advisable to apply nitrogen and also potassium shortly after the trees blossom when an estimate of the crop can be made. With tung trees growing on coarse-textured soils, it has been found advantageous to apply about half the fertilizer when the crop is set and the remainder six or eight weeks later (19). However, no advantage of splitting the application for the trees on the finer textured, sandy-clay soils has been found. Nonbearing trees are most advantageously fertilized at about the time growth starts.

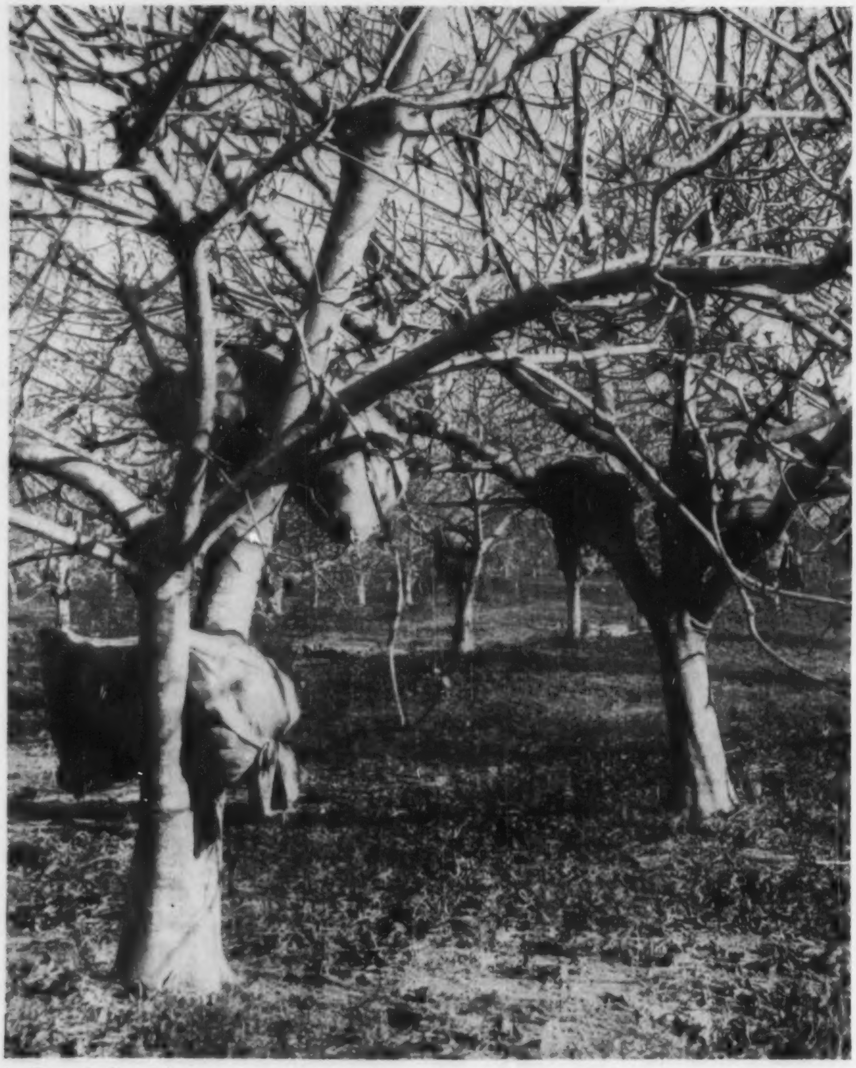
Observations indicate that the fertilizer is most effective if spread rather evenly over all or most of the soil beneath the branches of the trees. Young trees are necessarily fertilized by hand, and the workmen must take care to spread the mixture evenly. Newly transplanted trees are sensitive to fertilizer, and none should be applied within 10 inches of the trunks. The fertilizer for bearing trees has to cover a large area, and it is difficult to do the work properly by hand. In most orchards, it is advisable to use a machine that passes along each side of the row of trees, spreading the fertilizer in a strip four to five feet wide. Some machines are designed to pass once down the row middles, throwing the fertilizer to both sides. These machines are suitable for use in orchards of very large trees with branches practically meeting between rows.

Method of Harvest

Tung fruit are allowed to drop from the tree at maturity. At that time, the hulls are pulpy, and the moisture content of the whole fruit is at least 60%, fresh-weight basis. The fruit must lie on the ground for a period of at least three or four weeks, during which the tissues of the hulls die and the moisture content of the fruit is reduced to 40% or less. The carpels of fruits that have laid on the ground for several weeks tend to break apart. Growers strive to complete the harvest while most of the fruits are still whole because the expense of searching for and picking up pieces of broken fruit among the dead leaves would be prohibitive. The fruits of some varieties, notably those of La Crosse, are especially predisposed to break apart and must be harvested early in the season. Fortunately, the oil content of the fruits does not deteriorate until warm weather sets in; oil declines only when chemical changes incident to germination begin.

Although some development work has been done on machines for harvesting tung, practically the whole crop is still gathered by hand. The harvest begins in late October and continues through the winter as weather permits. The pickers usually work in crews of 15 to 20 under the supervision of an overseer. The grower pays the pickers on a piece-work basis and must also provide transportation to and from the orchard. A common practice is to contract with the owner of a bus to transport and supervise a crew of pickers. This contract is usually on a piece-work basis. Thus, it is to the contractor's advantage to employ only good pickers, who will gather a large number of bushels daily.

Owners of extensive orchards frequently provide a tractor-drawn trailer for each crew of 15 to 20 pickers. The baskets are then dumped directly into the trailers, which are hauled to a central point where the fruit is loaded into transport trucks.



4. Tung fruits picked up from the ground usually must be dried before they can be processed. Many growers sack the fruit and dry them in the manner illustrated above. Photo by Crops Research Division, ARS, USDA.

However, the majority of growers empty the baskets of fruit into burlap sacks which are hung in the branches of the trees to dry (Fig. 4). They then require one "sack man" for six to eight pickers. At a later date, they must remove the sacks from the trees and haul them to some convenient point for emptying into transport trucks. The sack method of handling the fruit involves considerable extra labor but may effect some savings in the cost of hauling to the mill and processing. In almost all instances the growers have their crops custom processed; and the charges for both hauling to the mill and the processing are based on the weight of the fruit as received at the mill. The quantity of tung fruit that weighs 2,000 pounds at 40% moisture will weigh only 1,412 pounds at 15% moisture (moisture percentages on fresh-weight basis). The saving in hauling and processing costs may offset part of the cost of handling in sacks.

Status of the Industry

The growers who first planted tung in the southern United States expected to sell their oil on the world market and make a profit. They did so in a limited way before World War II and for a short time subsequently. However, during the war the entire production of the domestic industry was purchased by the Federal Government for military use at a ceiling war price that netted the growers handsome profits. The protective-covering and other industries that normally use the oil conducted research and worked out formulae that enabled them to produce acceptable products containing little or no tung oil. Thus, in the years immediately after the war when the Nationalist Government of China shipped large quantities of tung oil to the United States in order to obtain dollar credit, the American growers were hard-pressed. Since 1948, the world market of tung oil has dropped still further, and today the American tung industry depends on a Government support price for its existence. In this respect, the tung industry differs little from some other agricultural industries that depend upon support prices, and many manufacturing industries that depend upon tariff protection. Possibly the world market for tung oil will improve. In the meantime, the American tung growers are striving to get their industry on a sound economic basis by lowering their cost of production and widening the market for tung oil.

Diseases, Pests and Controls

Tung trees in the southern United States are known to have been attacked since 1925 by the fungus *Mycosphaerella* (*Cercospora*) *aleuritidis*, which causes angular, dark-colored spots on the leaves. For many years, this fungus was comparatively innocuous, but apparently a more virulent strain of the organism arose about 1951 and premature defoliation began to take place. At first, the defoliation was limited to a few orchards in Louisiana, but by 1958, it had become widespread throughout the whole Tung Belt. One of the most serious effects of the infection is loss of oil content of the fruit. The cost of production of tung oil could be reduced materially by finding an effective and inexpensive control for this disease.

Although it is not economically feasible to control this disease by spraying with Bordeaux mixture, experimental plots have been kept practically free of the fungus by this means. During the period 1956-58, inclusive, fruit from sprayed plots has contained about 3 percentage units more oil than fruit of corresponding check plots. Since, in processing, about 86% of the total oil is recovered, the disease causes a loss of more than 50 pounds of marketable oil per ton of whole fruit. Also, the cost per ton of harvesting and hauling the crop to the mill is higher than that of fruit of good oil content, because each fruit is lighter, the weight per

bushel is less, and a smaller weight can be hauled in a transport truck. The ultimate solution of this problem is breeding of *Mycosphaerella*-resistant varieties of tung. Research is also in progress to determine whether this fungus can be controlled by oil mists as is a leaf spot of banana caused by a closely related organism. Oil mists are relatively inexpensive and probably would be economically feasible for the tung grower.

The tung tree in the United States is attacked by several other fungus and bacterial diseases. A fungus root rot caused by *Clitocybe tabescens* occurs on native oak and other forest trees. It may attack tung planted on newly cleared land, but usually it kills only an occasional tree. The reduction in stand does not justify control measures. Tung is also subject to a thread blight caused by *Pellicularia koleroga*, a nut rot caused by *Botryosphaeria ribis*, a black rot canker caused by *Physalospora rhodina*, and a bacterial leaf spot (*Pseudomonas aleuritidis*). None of these diseases causes sufficient damage to warrant control measures.

Insect pests are not a serious problem. The fruit and leaves of the tung tree are toxic to most animal life (28). Occasionally, the pink boll worm, *Pectinophora gossypiella*, may devour a few green tung fruit before it succumbs, and the same is true of grasshoppers (sp), which sometimes eat the leaves. Outbreaks of cottony-cushion scale (*Icerya purchasi*) occur occasionally, but the vedalia beetle (*Rodolia cardinalis*) usually appears and destroys the scale. Occasionally, the oleander scale (*Aspidiotus hederae*) infests the tung tree, but it, too, falls victim to predators.

Physical Environmental Factors

Frosts and freezes also cause serious losses. The tung tree annually passes through an extremely wide cycle in cold resistance. When fully dormant in winter, it is unharmed by temperatures as low as 8° to 10° F., but as growth is starting in the spring, the immature buds, blossoms, young fruit, and even the wood are extremely susceptible to cold. Also, cold weather sometimes comes early in the fall and damages blossom primordia and immature shoots. It is noteworthy that during the dormant season tung trees are uninjured by winter temperatures that kill trees of the King orange (*Citrus nobilis*), but at about the blossom period, tung trees are seriously injured by temperatures that do not harm the orange tree. The Crop Reporting Service of the U. S. Department of Agriculture has estimated the annual production of tung in the United States since 1939. Although in most years some slight damage has occurred in local areas, crop loss from frosts and freezes was negligible on an industry-wide basis in 12 of the 21 crop years, 1939-1959, inclusive. During the remaining nine years, serious damage occurred, ranging up to practically complete loss of the whole crop in 1955. It is calculated that the aggregate loss over the entire period was more than 20% of the potential production (25). Instead of an aggregate total production of about one million tons, the industry would have produced 1¼ million tons if there had been no loss from frost.

Conventional means of combating frost such as heating with oil and use of wind machines are not economically feasible for the tung industry. There is some evidence that the resistance of the tung tree to cold can be increased, at least at certain times of the year, by nutritional means (30). This approach to the problem is presently the subject of intensive research.

Another possibility is to develop a tung tree that does not blossom so early in the spring. The blossoms of *Aleurites fordii* open with the first warm weather in the spring. Shoot growth is made subsequent to blossoming. Trees of *A. montana* produce pistillate flowers on the ends of shoots of the current season; thus, the

blossoms appear after, rather than before shoot growth is made. Unfortunately, the characteristics of *A. montana*, other than its blossoming habit, are undesirable commercially. The oil is inferior, the tree is tender to cold, and the hulls of the fruit are so woody that no machine now available will hull out the nuts. Nevertheless, these two species have been hybridized in the hope of obtaining a tree having most of the characteristics of *A. fordii* combined with the blossoming habit of *A. montana*. Progress in this work has been slow. Although the two species have the same number of chromosomes, the hybrids exhibit a high degree of sterility. Backcrossing of hybrids that have a satisfactory blossoming habit on trees of *A. fordii* seems to offer the best promise of obtaining the desired result. Even at best, however, breeding of this type is a long-term project.

Research on culture and fertilization of tung has already greatly increased yields and correspondingly decreased cost of production. While some refinements in cultural practices are still to be worked out, future progress in this field of research is likely to be limited.

In 1939, the Crop Reporting Service of the U. S. Department of Agriculture estimated total production in southern United States at 1,100 tons; the preliminary estimate for 1958 was 134,500. Although still a small industry, tung growing occupies an important place in the economy of certain areas of the deep South. The value of the tung crop in Mississippi is greater than the aggregate value of all other horticultural crops, and it ranks fifth or sixth among all cash crops in that state. Under favorable economic conditions, soil and climate of the southeastern states would permit a vast increase in the tung industry. From the farm-management standpoint, tung is an excellent crop for diversifying southern agriculture. It requires comparatively little labor during the summer and offers employment during the winter when there is little other farm work. Tung growing makes an excellent companion enterprise with beef production.

A lower cost of production and wider markets are needed. Tung growers of the southern United States are aware of this fact and have joined with growers of Argentina to form the Pan-American Research and Development League, which is dedicated to finding new end uses for tung oil and developing present markets. Growers also look hopefully to work on utilization now in progress in the Southern Utilization Research and Development Division of Agriculture Research Service, U. S. Department of Agriculture. This work is the subject of a companion article by Dr. L. A. Goldblatt on processing and utilization.

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The Tung Industry. II. Processing and Utilization

Processing of tung fruit to produce high quality tung oil has been subjected to continuous modification, improvement, and mechanization. Domestic tung oil is high in eleostearate content and normally meets all recognized specifications. The basic chemistry of the major components of tung oil, the eleostearic acids, has been well established. Although the major industrial use of tung oil continues to be in the drying oil field, research is under way to take advantage of the unique chemical character of the eleostearic acids. Progress is being made in the utilization of the by-products, tung hulls and tung press cake.

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Growing and harvesting the tung crop as described by Dr. Potter in the preceding article, is only half the battle for the development of a thriving American tung industry. Processing the crop to provide commercially useful products and developing adequate markets for those products comprise the other, and no less important, half. This means not only development of improved, efficient, and economical processes and equipment for extracting high quality tung oil but also increased knowledge of the composition and basic chemistry and technology of tung products to improve and expand their utilization.

The tung industry is fortunate not only in that a vast amount of research which has benefited all phases of the industry has been performed but also in the fact that the literature in which this research is reported has been so well collected, summarized, and made readily available. A comprehensive "Abstract Bibliography of the Chemistry and Technology of Tung Products, 1875-1950" (42) provides an invaluable key to the literature of tung. This contains nearly 3,000 references to, and abstracts of, articles and patents dealing with all phases of the tung industry. Two books in German on the chemistry, processing, and uses of tung oil are available (12, 15). Finally, "Tung Oil Review, 1951-1952" (40) and the abstracts of current literature in Chemical Abstracts and in the pages of the Journal of the American Oil Chemists' Society provide ready access to all the significant recent literature.

Processing Tung Fruit to Produce Tung Oil

Tung oil is by far the most valuable product of the tung crop. Various operations must be performed after harvesting to obtain tung oil, and many factors affect the amount and quality of the oil obtained. In China, where tung culture and processing is an ancient art, everything is done by hand. The methods employed in China, which are primitive and have shown little improvement even in recent years, have been adequately described by Blackmon (5). In the United States, where tung culture is new, machinery is used insofar as possible, and processes have been subjected to continuous modification, improvement, and mechanization. In consequence, American tung oil is generally superior to that produced in China and has sometimes commanded a premium of several cents per pound.

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The Milling Process. The milling of tung fruit entails essentially the following operations: The fruit is partially dried, and the hulls and some of the shells are removed. The separated seeds with suitable moisture and shell content are then ground, preheated, and passed through a continuous screw press to remove the oil. The expressed oil is passed through a filter press and pumped to storage tanks. The residual meal is discharged from the end of the press in the form of a cake. A flow diagram of the milling process as carried out in a typical mill with a capacity of about 90 tons of whole fruit per 24 hours is shown in Figure 1 (23). Tung fruit in bags or in bulk is unloaded from trucks to the unloading bin (A). The trucks are weighed before they are unloaded, reweighed when empty, and samples are taken as the fruit enters the bin. From this bin the fruit is carried by a conveyer belt to a second bin (B) designated as the huller bin. From this bin, located above the huller, the tung fruit passes through a rotary screen (C) which removes most of the dirt and loose particles of hulls. The fruit is then broken down in a huller (D).

Hulling. Two different types of hullers are in common use, a disc type and a drum huller (43). In the disc type, which is used primarily in the tung processing mills, the fruit is forced between a stationary and a rotating disc set sufficiently far apart (about 1.5 inches) to permit passage of the hulled fruit or seed

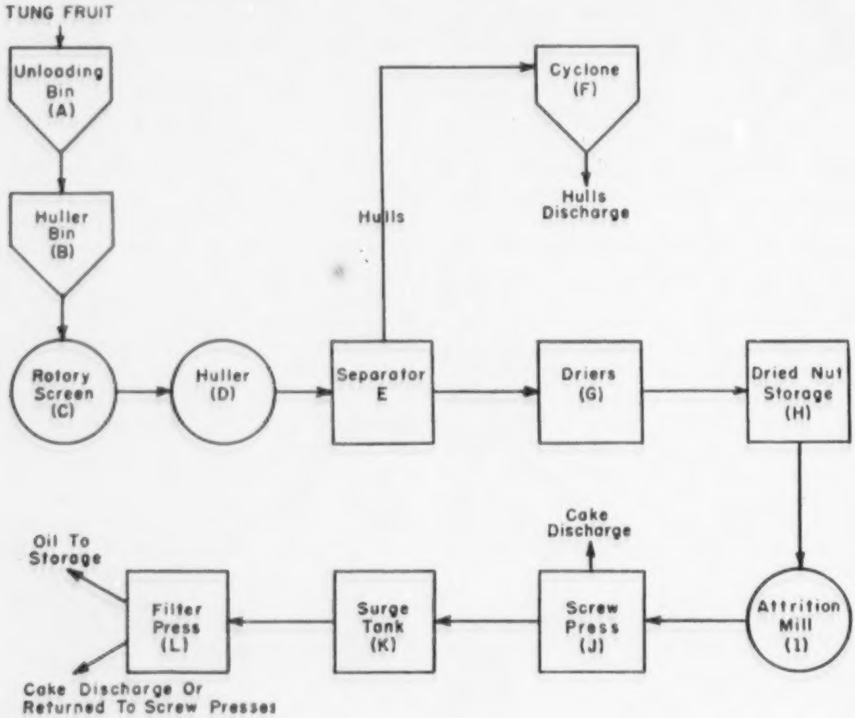


Fig. 1. Flow diagrams of tung milling.

but not the whole fruit. This type of huller, in addition to removing all of the hulls, ordinarily removes about half of the shells and breaks some of the kernels, the amount of breakage varying with the moisture content of the fruit and the setting of the discs. For efficient operation of the huller the fruit should contain between 15% and 20% moisture. Fruit containing 35% or more of moisture cannot be hulled in a disc huller. On the other hand, if very dry fruit is processed, there is excessive loss of oil because pieces and whole kernels remain in the hulls. If the fruit contains 15% to 20% moisture, the loss of oil is small. Broken seeds, when moist, rapidly develop free fatty acids through a hydrolysis of the oil in the kernels, and they heat spontaneously unless dried to about 10% moisture, or less, without delay (32). For this reason disc hullers are used primarily at the tung processing mills.

Although the disc huller cannot handle fruit with high moisture content, the drum huller operates very satisfactorily on fruit with 30% to 50% moisture and leaves all or most of the shell intact (43). The drum huller typically consists of a drum carrying fluted hard rubber flanges which revolve inside an iron shell with perforations just large enough to allow individual hulled nuts to pass through. The fruit should be moist and pliable because, if it is dry, the hull becomes tough and leathery and the kernels will be torn up while going through the drum huller. Fruit with 30% to 50% moisture can thus be hulled with little breakage of shells.

This type of huller was developed primarily for operation in the field where fruit with this higher moisture content is encountered and where the hulled fruit cannot be processed promptly. Artificial drying of the whole fruit is generally believed to be uneconomical, in comparison with natural drying, because of the cost of the equipment and the large amount of heat and time required. Removal of the hulls before drying and storage is economically feasible because the heat required for drying is decreased since the hulls contain more than half the moisture of the fruit and have no value as a source of oil. Hulling in the field not only decreases by about 50% the weight of the material hauled to the mills but leaves the hulls in the field where they are useful as mulch and fertilizer since the hulls contain about 3% potash and small amounts of nitrogen and phosphorus (24). However, field hulling results in loss of bits of cracked kernels, and it appears that relatively little fruit is now being hulled in the field. One processor who installed equipment for artificial drying of whole fruit in 1958 is reported to have operated it at a good rate and low cost.

Drying Nuts. The mixture of hulled nuts and hulls (containing 15% to 40% moisture) is discharged to a separator (E), where the loose hulls are removed by suction and discharged through a cyclone (F). Any unhulled nuts are returned from the separator to the huller. The hulled nuts then pass through driers (G). Driers of various types have been tried in pilot plant experiments. It was found that a louver-type drier operating at temperatures below 200° F. gave good results and was preferable to other types of driers tested. Vertical, louvered seed driers in which warm air is drawn through a layer of seed 12 to 24 inches deep are now commonly used. Better yields of oil are obtained by keeping the temperature below 140° F. and by drying the seed to a moisture content of six to ten percent. The use of these vertical driers has increased the capacity of the tung mills and the efficiency of oil expression although occasionally fruit will be encountered dry enough so that no further drying is required. From the driers the nuts are discharged into storage bins (H) where they usually have time to cool before they are further processed.

Grinding. Dried nuts are taken from the storage bins to an attrition mill (I) where they are ground to a coarse meal. This mill consists of a rotating grooved plate revolving past a grooved stationary plate. The clearance between the plates can be varied to control the particle size of the meal. Typically, a clearance of about ¼ inch is used, and the largest particles would be about ¼ inch in cross section.

Pressing. The ground meal passes to the press (J). It has been found that continuous pressing is preferable to hydraulic expression or solvent extraction. The ground meal entering the press should be hot (200-205° F.) and should contain three to five percent moisture. Since the meal as it leaves the attrition mill usually has a higher moisture content and is only slightly warm, most continuous presses are equipped with a steam jacketed "conditioner" or "tempering bin" by means of which the temperature and moisture content of the meal entering the press may be adjusted. The press itself typically consists of a center shaft of interrupted screw construction within a cylinder of steel bars set close together. The screw moves the meal forward against a restricted opening between the cylinder and the center shaft, and pressure on the meal is gradually built up to about 12,000 to 20,000 pounds per square inch. The expressed oil flows out through the narrow slots between the bars. The residue, containing on the average about five percent oil, is discharged in the form of a cake through the constricted opening at the far end of the cylinder.

There is some difference of opinion in the industry regarding the optimum amount of shells and hulls which should be left with the kernels. An attempt is made to remove all of the hulls, but a certain amount of shell is required to provide friction and drainage during expression of the oil. If too little is used, an oily mush is obtained from which the oil cannot be removed efficiently; if too much is used, there is excessive wear on the expeller and loss of oil (25). Good results have been reported with meals containing 20% shells and 4.2% moisture; slightly less favorable results were reported with a meal containing 30% shell and 3.5% moisture. Meal containing all of the shell has been reported to process as efficiently as that containing about two-thirds of the shell. The cake as it comes from the presses is hot (about 200° to 210° F.), and it must be allowed to cool before storage to decrease danger from spontaneous combustion. Sufficient cooling usually takes place on the conveyors during transfer to storage.

The crude oil obtained from the screw press flows into a surge tank (K). This crude tung oil contains a considerable amount of impurities, principally from the ground kernels and shell in the meal. It is necessary to pass the oil through a filter (L) to remove them. This is usually done by passing the oil from the surge tank to a steam-jacketed tank where it is heated to about 180° F. and agitated with about one percent of a filter aid such as diatomaceous earth. Then, under a pressure of about 40 pounds per square inch, it is filtered through a filter press with plates precoated with a thin layer of filter aid or through a plate and frame filter press using filter cloth. Filtration is continued until an excessive amount of pressure is required to maintain the flow of filtered oil. The flow of crude oil to the filter press is then shut off, and air is blown through the press to remove as much oil as possible from the cake which is then removed. The filtered oil is pumped to storage.

Recovery of Oil from Filter Press Cake. The filter press cake may contain up to 50% oil and may amount to as much as 20% of the total expressed oil. To recover as much oil as possible from

this filter press cake two methods are commonly used. In one method the cake is added a little at a time to the tung meal entering the continuous screw press. In the other the cake is allowed to accumulate, and a separate pressing is made from it at about weekly intervals after it has been thoroughly mixed with a considerable amount of press cake and hulls. Neither method is entirely satisfactory as it is not possible to obtain a final press cake of low oil content. The recovery of oil from filter press cake by solvents is sometimes done commercially. Laboratory tests have shown that, when tung filter cake is mixed with an equal amount of tung press cake, more than 98% of the oil can be extracted with petroleum solvents (34). To date two mills have installed equipment and have successfully applied solvent extraction to recover tung oil from filter press cake.

Solvent Extraction of Tung Oil

Mechanical presses generally leave at least three to four percent oil in the press cake and at times as much as ten percent. Laboratory and pilot plant scale experiments have shown that it is feasible to solvent-extract properly prepared tung meal and obtain good quality oil in yields superior to that obtained by mechanical methods. A suitable process calls for reducing the kernels to a medium fine meal with corrugated rolls, flaking the meal containing about seven percent moisture with smooth rolls, extracting with hexane, filtering the miscella, and distilling (prefably under reduced pressure) to recover the oil (13, 14.). Although solvents are used for recovery of residual oil from tung filter cake and press cake, tung oil is not now recovered commercially from whole tung meal by solvent extraction. One mill is known to prepress the meal and subsequently extract the residual oil-rich meal with solvent.

Efficiency of Recovery of Tung Oil.

The efficiency of individual mills varies considerably depending upon the condition of the fruit, the type of press used, and the condition of the processing equipment. It has been found, over several seasons, that with efficient operation a recovery of 16.5% oil from tung fruit containing 19.5% oil can be obtained. Commercial mills have reported the following representative yields on the component parts of the fruit (31):

Oil	14.7 to 19.5% of the fruit
Oil	42.1 to 53.2% of the meal
Oil	310 to 390 pounds per ton of air dried fruit*
Oil in Cake	3.1 to 6.6%
Meal	40 to 45% of the fruit
Hulls & Shells	55 to 60% of the fruit

A material balance analysis (23) run on a typical commercial screw press mill has afforded the following results. Whole fruit with a moisture content of 10.7% and oil content of 21.30% produced hulled nuts containing 6.85% moisture and 40.32% oil. The dry hulled nuts contained 2.55% moisture and 42.82% oil. The screw press cake contained 2.52% moisture and 6.36% oil. Only 78.2% of the oil in the fruit was recovered as filtered oil. Of the rest, 8.9% of the oil in the fruit was lost in the hulls, 7.1% was lost in the screw press cake, and 5.9% was lost in the filter cake. The filter cake contained 3.07% moisture and 43.44% oil. In another mill run, in which the filter press cake was fed back through the screw presses, the recovery of the filtered oil amounted to 81.7% of the oil originally present in the fruit, and the loss of oil in the screw press cake was increased to 10.1%.

*Yields as low as 240 pounds of oil per ton of "air-dried" fruit have been reported after very rainy weather.

Storage of Oil

The problem of the prolonged storage of tung oil is a continuing one. During World War II the supply of tung oil from China was practically cut off, and stocks in the United States were placed under allocation and conserved as far as possible. In some cases oil stored in relatively small tanks exposed to the weather developed a layer of polymerized and oxidized oil several inches thick at the surface. Such layers did not form in large tanks or in protected tanks. Domestic oil stored in a large tank showed only a slight increase in acidity during a period of about two years. It retained a good color and showed no evidence of gel formation. A controlled storage experiment carried out with domestic tung oil over a period of three and a half years showed that tung oil stored in clean, well-filled containers still met specifications of the American Society for Testing Materials (26). Storage locale (indoor, outdoor, sheltered, or unsheltered containers) and the exterior coating on the containers in exposed locations were found to be of less importance than the protection of the stored oil from atmospheric oxygen. It was found that uncontaminated tung oil does not spontaneously isomerize during storage and that the most pronounced effect of prolonged storage of tung oil is a shortening of the time required to cause the oil to gel on heating.

Specifications for Tung Oil

Tung oil is generally marketed in conformity with federal specifications for tung oil (52) or with specifications set up by the American Society for Testing Materials (2). These prescribe that raw tung oil shall conform to the following requirements:

Specific gravity, 25/25° C.	0.935[a] to 0.938
Acid number (alcohol-benzol), max.	8.0
Saponification number	189 to 195
Unsaponifiable matter, max., percent	0.75
Iodine number (Wijs), min.	163
Gel time, max., minutes	12
Refractive index at 25° C.	1.5165 to 1.526
Appearance	Clear and transparent at 65° C.
Color	Not darker than a freshly prepared solution of 1.0 g. of $K_2Cr_2O_7$ in 100 ml. of pure H_2SO_4 (sp. gr. 1.84) or its equivalent in iron-cobalt solution or in Lovibond glasses.

[a] For American grown tung oil, the minimum specification may be as low as 0.933.

The quantitative requirements of federal specifications for raw tung oil are identical except that the color may be as dark as a solution containing 1.041 g. of $K_2Cr_2O_7$ in 100 ml. H_2SO_4. Tung oil is generally light golden or light amber in color.

The averages for the significant characteristics of more than 70 samples of domestic tung oils obtained over three milling seasons have been reported (27), and it was found that domestic tung oil is a highly uniform product. Practically all of the oils met A. S. T. M. specifications without difficulty.

Physiological Properties of Tung Oil

Tung oil is still utilized in China as an old Chinese drug. The oil is given in China as a remedy for insanity and in cases of metallic poisoning. It is applied as a stimulant to carbuncles, ulcers, swell-

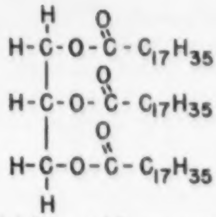
ing, burns, and bruises, and is a constant ingredient in native plasters (8).

There have been many reports of dermatitis—inflammation, itching, and blistering—on contact with tung oil. Many of the cases reported are doubtless due to admixture or confusion of the oil with Chinese (or Japanese) lacquer oil produced from the poisonous sumach *Rhus toxicondendron*. On the other hand, it appears that some cases of dermatitis are clearly not due to these causes. Swaney (49) has reviewed the literature on the subject.

When taken internally tung oil has a strong purgative and emetic effect. It is not edible. During World War II numerous cases of adulteration of edible oils with tung oil were reported in Germany and in China. There were numerous complaints due to the purgative action, but apparently nothing more serious was encountered. Grollman has referred to the use of tung oil to reduce hypertension (18). Numerous successful uses of processed tung oil in industrial surgery have been reported (47). A tung oil skin lotion for which remarkable healing properties are reported (10) has been marketed. Tests for biological activity as anticancer agent, larvicide, anthelmintic, insect repellent, rodent repellent, herbicide, and plant growth regulator were essentially negative (1). There has been an abiding interest in the alleged curative properties of tung oil, and from time to time statements are made about the use of tung oil for one or another curative purpose, but a critical study of the literature purporting to support these claims indicates little convincing evidence that tung oil is beneficial in medicine (1).

Composition of Tung Oil

Practically all vegetable oils are glycerides that is, fatty acid esters of glycerol. The structure of a typical glyceride (tristearin) may be represented thus:



The chief fatty acid component of tung oil is eleostearic acid, accompanied by smaller amounts of other acids, particularly oleic, linoleic, and palmitic acid, all combined as glycerides. Numerous reports of more or less detailed analyses of various tung oils are found in the literature (42). Domestic tung oil, which is produced exclusively from kernels of *Aleurites fordii*, normally contains about 78% eleostearic acid, ranging from 73% to 85% (27). One of the more recent analyses of such an oil (20) made with the aid of spectrophotometric examination and fractional crystallization from solvents afforded the following result for the component fatty acids: eleostearic acid, 82%; linoleic acid, 8.5%; oleic acid, 4%; saturated acids (chiefly palmitic acid) 5.5%.[3]

[3] Two methods are commonly used to indicate the fatty acid composition of glyceride oils. These are referred to as the component fatty acid basis and the glyceride or oil basis. Calculations of fatty acid composition, fatty acid basis, are made on the assumption that the sum of all the fatty acids present in the oil corresponds to 100%. Calculations of fatty acids composition, glyceride basis, are made on the assumption that each fatty acid is combined with its proportionate share of glycerol. On this basis the total fatty acid content of most naturally occurring oils is 95.6%, the remainder comprising the glycerol. In actual practice a hundred grams of a vegetable oil, or glyceride, is convertible into about 96 grams of fatty acid and 10 grams of glycerol or 106 grams of both fatty acid and glycerol because about 6 grams of water are chemically added to the oil to cause the conversion. This conversion is referred to as hydrolysis. To convert fatty acid composition (glyceride basis) to fatty acid composition (fatty acid basis) simply multiply by the factor 100/95.6. Conversely, to convert the composition (fatty acid basis) to glyceride basis, simply multiply by 0.956.

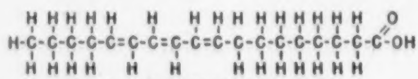
Tung oil is also produced commercially from *Aleurites montana* particularly in South China and Africa. This oil normally contains a somewhat lower proportion of eleostearic acid, ranging upward from about 70%. In a number of oils from both *A. fordii* and *A. montana* examined by Hilditch (19), he found the eleostearic acid content varied between 72% and 82%. One sample of oil from authentic *A. montana* nuts contained as much as 78%, a proportion of eleostearic acid as high as that usually associated with *A. fordii.* Hilditch concluded that the differences in eleostearic content are more likely due to environmental than to genetic influences. On the other hand, investigators in Florida have found *A. montana* oil to be consistently lower in eleostearate content than *A. fordii* oil grown in the same environment (11).

Chemistry of Eleostearic Acid

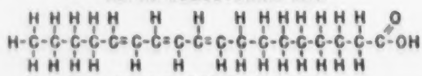
Since tung oil is composed so largely (about three-fourths) of a single acid, eleostearic acid, it is well to consider first the chemistry of this very unusual acid in some detail before entering upon a discussion of the utilization of tung oil, which is based essentially on the chemical behavior of the oil.

It is now known that eleostearic acid possesses a straight chain (non-branched) of 18 carbon atoms, that each molecule of eleostearic acid contains three unsaturated centers or double bonds, and further that these double bonds are in the 9:10, 11:12, and 13:14 positions. It is this arrangement of three alternating double and single bonds that gives to eleostearic acid its unique properties and to tung oil its unusual ability to thicken and polymerize to a viscous material when heated to a high temperature (280° C.) for a few minutes. A system containing alternating double and single bonds is referred to as a conjugated system. Such a system undergoes many reactions, e. g., Diels-Alder reactions, that other equally unsaturated systems do not undergo if the double bonds are not conjugated. Thus, linolenic acid, the chief component of linseed oil, is isomeric with eleostearic acid; but the three double bonds in linolenic acid are in the 9:10, 12:13, and 15:16 positions, and it is far less reactive chemically than is eleostearic acid.

There are eight different geometric isomers or chemical modifications of eleostearic acid, all with a straight chain of eighteen carbon atoms and with the three double bonds in the 9:10, 11:12, and 13:14 positions, theoretically capable of existence and differing only in the relative spatial position or arrangement of the hydrogen atoms about the double bonds. The structure of two of these isomers, designated as *alpha*-, and *beta*-eleostearic acid are shown:



ALPHA-ELEOSTEARIC ACID



BETA-ELEOSTEARIC ACID

It will be noted that the hydrogen atoms on carbons 9 and 10 of *alpha*-eleostearic acid are on the *same* side of the double bond, whereas for all the other double bonds the hydrogen atoms are on *opposite* sides of the double bonds. A double bond in which the two hydrogen atoms are on the same side of the double bond is said to have a *cis* configuration and one in which the two hydrogen atoms are on opposite sides is said to have a *trans* configuration. Accordingly, *alpha*-eleostearic acid is 9-*cis*-11-*trans*-13-*trans*-octadecatrienoic acid, and *beta*-eleostearic acid is 9-*trans*-11-*trans*-13-*trans* - octadecatrienoic acid. Such isomers are known as geometric isomers or stereoisomers. Another naturally occurring stereoisomer of eleostearic acid is punicic acid, readily ob-

tainable from pomegranate seed oil, to which has been assigned the structure 9-*cis*-11-*trans*-13-*cis*-octadecatrienoic acid. Both *alpha*- and *beta*-eleostearic acids have been known for some 50 years, but only recently has it become possible, by an ingenious application of infrared spectroscopy and recently developed chemical procedures and correlations, to establish the correct configuration of these two acids (4, 36). These structures have recently been confirmed by an elegant synthesis of eleostearic acid (9).

Effect of Cis-Trans Configuration on Properties. While this difference in the relative position of a single hydrogen atom (on the same or on the opposite side of a double bond as another hydrogen atom) may appear to be insignificant, it may, and frequently does, have a quite significant effect upon both the physical and chemical properties. This difference results in marked differences in the properties of both the eleostearic acids and of tung oil. For example, one of the best known, easily determined, and useful physical characteristics of a pure compound is its melting point. The melting points of pure *alpha*- and *beta*-eleostearic acids differ by more than 20 degrees; the melting point of the pure *alpha*-acid is 49.2° C. and of the pure *beta*-acid is 71° C. (22). This effect is carried over, and even magnified, when the acids are incorporated in the glyceride, as in tung oil. Thus, normal tung oil, which contains no *beta*-eleostearic acid remains a clear liquid at refrigerator temperatures (7° C.). A tung oil containing 17% *beta*-acid (as glyceride) remains liquid at room temperature (25° C.) but solidifies in the refrigerator. Another oil began to crystallize at room temperature when it contained 24% *beta*-acid and appeared to be completely solid at room temperature when it contained about 40% of *beta*-acid (48). One polymorphic form of *beta*-tung oil was found to have a melting point of 52.8° C. (45).

Isomerization of Eleostearic Acid. The conversion (isomerization) of *alpha*- to *beta*-eleostearic acid is an equilibrium reaction, but the equilibrium greatly favors the *beta*-modification and is greatly facilitated by even traces of various catalysts such as iodine or sulfur. For example, blending normal tung oil with as little as one-tenth of one percent of a saturated aqueous solution of potassium iodide will result in a copious precipitation of isomerized oil on exposure to diffuse daylight at room temperature for a few hours (22). This facile conversion of liquid tung oil into solid by means of even traces of certain catalysts sometimes causes inconvenience in handling and utilizing tung oil. Discovery of a tank car of tung oil which has solidified in transit can be disconcerting.

Numerous other physical properties, such as refractive index, boiling point, specific heat, heat of fusion, and viscosity are also affected by this isomerization (55). Of particular importance is the difference in absorption in the ultraviolet region because this provides a basis for the quantitative estimation of the *alpha*-, *beta*-, and total eleostearate content of tung oil. The absorption curves for pure *alpha*- and *beta*- eleostearic acid are shown in Figure 2. Each of the acids has three characteristic maxima in the region 260 to 280 millimicrons. For the *alpha*-acid the biggest maximum (in cyclohexane) lies at 271.5 mμ (absorptivity, $a = 176.7$) and for the *beta*-acid it lies at 269.0 mμ ($a = 201.8$). With the aid of these absorptivities simple measurement of the absorptivities of a solution of tung oil in cyclohexane at these two wave lengths permits ready calculation of the *alpha*- and *beta*-eleostearate content (22).

The isomerization of *alpha*- to *beta*-eleostearic acid also affects the chemical properties, but the difference is generally only one of degree. In general the *beta*-form reacts more readily than does the *alpha*- form but this is not invariably the case.

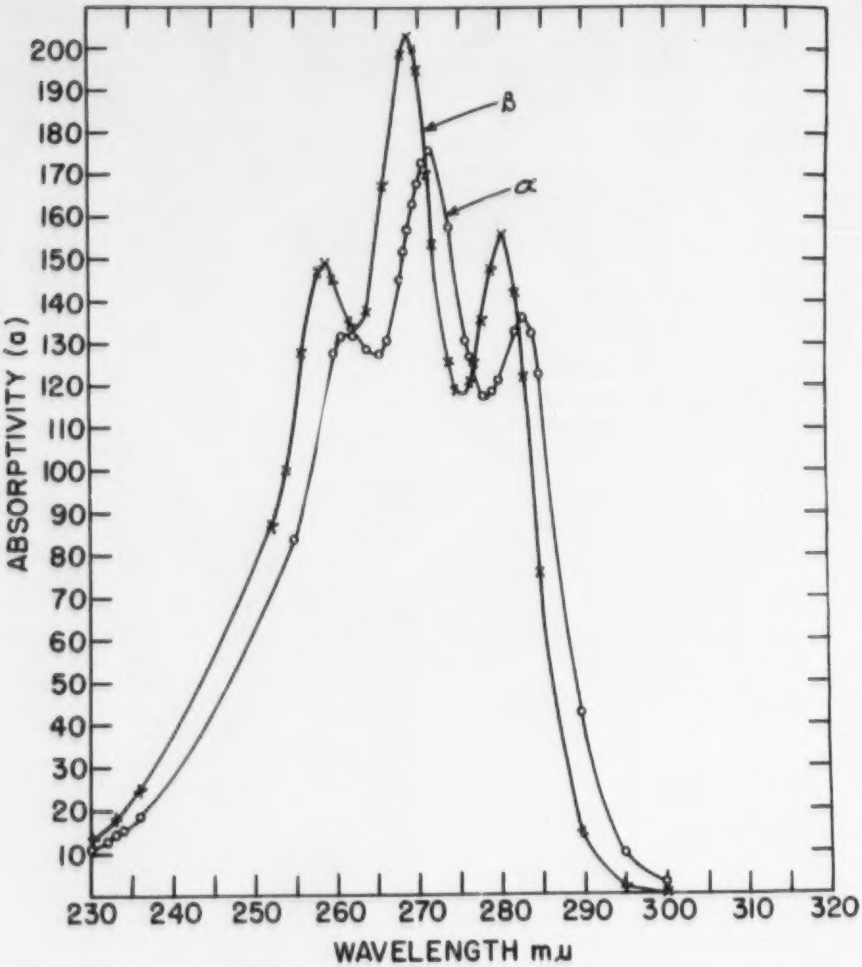


Fig. 2. Ultraviolet absorption of *alpha*- and *beta*-eleostearic acids in cyclohexane.

Chemical Reactions of Eleostearic Acid

If one considers the various possibilities of chemical reaction of an acid such as eleostearic acid wtih different chemical reagents, one finds that the different reactions can be classified into three groups or types. These are (1) the reactions of the carboxyl (COOH) group at the end of the chain, (2) the reactions of the unsaturated centers or double bonds, and (3) the reactions of the various hydrogens attached to the carbon atoms of the chain. A few representative reactions of each type will be discussed briefly.

Carboxyl Group Reactions. The reactions of the carboxyl group of eleostearic acid are typical of those of other long-

chain fatty acids. Probably the most common reaction of the carboxyl group is the formation of metallic salts. Reference to the preparation of numerous salts such as those of barium, calcium, cobalt, copper, lead, manganese, potassium, silver, and sodium will be found in the literature (42). Such salts are readily formed by reaction with the metal hydroxide, oxide, or by double decomposition as indicated by the equations below.

$$C_{17}H_{29}COOH + KOH \longrightarrow C_{17}H_{29}COOK + H_2O$$
$$2\,C_{17}H_{29}COOH + CaO \longrightarrow (C_{17}H_{29}COO)_2\,Ca + H_2O$$
$$C_{17}H_{29}COOK + AgNO_3 \longrightarrow C_{17}H_{29}COOAg\downarrow + KNO_3$$

Another extremely common reaction of the carboxyl group is that with alcohols to form esters. Numerous esters have been prepared including not only those of the monohydric alcohols such as methyl, ethyl, propyl, butyl, and allyl alcohol, but also of polyhydric alcohols such as ethylene glycol, pentaerythritol, and mannitol (42). Like most esters, these can be prepared by direct reaction with an alcohol (esterification) in the presence of an acidic catalyst, e. g. 1% sulfuric acid. However, like most conjugated acids, eleostearic acid esterifies more slowly than do the corresponding non-conjugated or less unsaturated acids (17). In the presence of the acid catalyst the *alpha*-acid undergoes some isomerization to the *beta*-acid (38). Because of the ease of polymerization of eleostearic acid through its double bonds, a certain amount of polymer is formed. Accordingly, a more convenient procedure commonly employed is ester exchange or ester interchange in the presence of a basic catalyst. Reactions of this type are illustrated below.

$$\underset{\text{Methyl eleostearate}}{C_{17}H_{29}COOCH_3} + \underset{\text{Butanol}}{C_4H_9OH} \xrightarrow{C_4H_9ONa} \underset{\text{Butyl eleostearate}}{C_{17}H_{29}COOC_4H_9} + \underset{\text{Methanol}}{CH_3OH}\uparrow$$

$$\underset{\text{Methyl eleostearate}}{C_{17}H_{29}COOCH_3} + \underset{\text{Butyl acetate}}{CH_3COOC_4H_9} \xrightarrow{CH_3ONa} \underset{\text{Butyl eleostearate}}{C_{17}H_{29}COOC_4H_9} + \underset{\text{Methyl acetate}}{CH_3COOCH_3}\uparrow$$

Glycerolysis (treatment with glycerol) is a reaction commonly employed by manufacturers of vehicles for surface coatings to permit subsequent introduction of additional modifying acids. This reaction has been carried out with tung oil to produce mixtures of mono-, di-, and triglycerides (33) e. g.

$$\underset{\text{Glycerol trieleostearin}}{(C_{17}H_{29}COO)_3\,C_3H_5} + C_3H_5(OH)_3 \rightarrow \underset{\text{A diglyceride}}{(C_{17}H_{29}COO)_2\,(OH)\,C_3H_5} + \underset{\text{A monoglyceride}}{(C_{17}H_{29}COO)\,(OH)_2\,C_3H_5}$$

Pure glycerol mono- or di-eleostearates have not been prepared.

Corresponding alcoholized products have also been obtained by treatment of tung oil with other polyols including ethylene glycol, pentaerythritol, trimethylolethane, and mannitol (42).

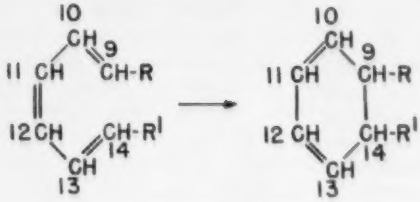
Owing to the ease of hydrogenation of the conjugated double bonds, the -COOH group of eleostearic acid cannot be reduced by the methods usually used for reducing other organic acids (high pressure hydrogenation or treatment with sodium and an alcohol) but conversion to eleostearyl alcohol has been effected by hydrogenation with lithium aluminum hydride (30) according to the equation:

$$C_{17}H_{29}COOH + H_2\ (LiAlH_4) \longrightarrow C_{17}H_{29}CH_2OH + H_2O$$

Other characteristic reactions of the carboxyl group which have been applied to eleostearic acid include conversion to the acid chloride ($C_{17}H_{29}COCl$), the amide ($C_{17}H_{29}CO\ NH_2$), the hydrazide ($C_{17}H_{29}CO\ NHNH_2$), and the anhydride $(C_{17}H_{29}CO)_2\ O$ (42).

Double Bond Reactions. The usual addition reactions common to unsaturated compounds are applicable to eleostearic acid. It readily undergoes numerous Diels-Alder type reactions characteristic of conjugated systems. Thus, it readily adds hydrogen in the presence of catalysts such as nickel, platinum, and palladium to produce stearic acid. Chlorine, bromine, and iodine can be added to produce halogenated derivatives. The product of addition of three moles of chlorine to eleostearic acid would be formulated as $CH_3(CH_2)_3$-$(CHCl)_6(CH_2)_7COOH$. However, halogenation conditions usually utilized to determine the degree of unsaturation result in incomplete addition so that under these conditions the eleostearic acids (and tung oil) appear to be less unsaturated than they really are. In fact, for a long time eleostearic acid was believed to have only two double bonds. However, methods have been developed which do give correct values for the degree of unsaturation of eleostearic acid containing materials by halogenation using mercuric acetate as a catalyst (41), and by quantitative catalytic hydrogenation using acetic acid as a solvent (35). Reaction with ozone (O_3) results in the formation of ozonides which, on oxidative cleavage, produce azelaic acid, and valeric acid. This reaction is of particular importance in establishing the position of the terminal bonds at the 9:10 position (producing azelaic acid) and the 13:14 position (producing valeric acid).

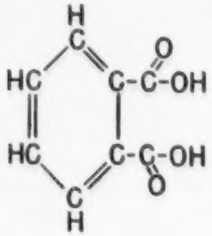
Certain reactions not common with other unsaturated compounds are noted in eleostearic acids by reason of the unusual sequence of three alternating double and single bonds. One of these reactions is cyclization. It is known that in organic compounds six-membered rings tend to form rather readily and that cyclic compounds containing six carbon atoms in a ring tend to be quite stable. It will be observed that in eleostearic acid the terminal carbon atoms of the double bond system comprise a chain of six carbon atoms. Accordingly, it is not surprising to find that eleostearates cyclize readily, joining at the ninth and fourteenth carbon atoms to form a six-membered ring. Paschke and Wheeler (38) have found that methyl eleostearate can readily be cyclized in good yield at the relatively low temperature of 250° C. The reaction which occurs can be formulated according to the following equation:



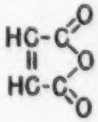
$R = -(CH_2)_7COOH$

$R' = -(CH_2)_3CH_3$

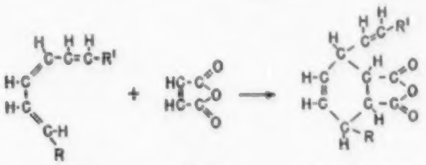
That the groups R and R[1] are actually attached to adjacent carbon atoms was established by the fact that the reaction product could be dehydrogenated (aromatized) to the corresponding benezene derivative and oxidized to the well-known ortho phthalic acid:



Diels-Alder Reactions. The ability of conjugated systems such as those present in eleostearic acid to undergo the Diels-Alder reaction has already been mentioned. The Diels - Alder reaction (for which Otto Diels and Kurt Alder were awarded a Nobel Prize in Chemistry) is a very general reaction and may be characterized as one involving 1,4-addition of an unsaturated compound to the terminal carbon atoms of a conjugated diene, forming an unsaturated six-membered ring compound. In order for a Diels-Alder reaction to occur readily there must be present a *trans, trans* conjugated diene and a dienophile (a "diene-loving" compound). Organic compounds which are suitable dienophiles are very numerous as even ethylene ($CH_2{=}CH_2$), the simplest of unsaturated compounds, can be used as a dienophile. However, relatively severe conditions of temperature and pressure are required unless the double bond of the dienophile is activated, for example by conjugation with another type of unsaturation such as the carbonyl group (C=O) or the nitrile group (C≡N). Maleic anhydride in which the



ethylenic double bond is activated by the two neighboring C=O groups is readily available and a particularly useful and reactive dienophile. The reaction which occurs may be illustrated as shown below:

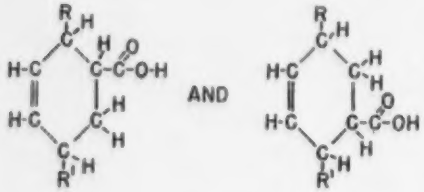


ALPHA ELEOSTEARIC ACID | MALEIC ANHYDRIDE | DIELS-ALDER ADDUCT

$R = -(CH_2)_3CH_3$ $R' = -(CH_2)_7COOR$

In *alpha*-eleostearic acid there is only one pair of *trans, trans* double bonds so only one adduct is formed. In *beta*-acid there are two pairs of *trans, trans* double bonds, and 1,4-addition can occur across the 9,12-position as well as across the 11,14-position. Nor are the compounds obtained by the maleic anhydride across the 11 and 14 carbon atoms of *alpha*- and *beta*-eleostearic acid identical because the residual (exocyclic) double bond in the one case has the *cis* configuration, while in the other it has the *trans* configuration.

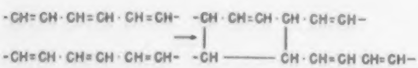
The dienophile used in the illustration above, maleic anhydride, is symmetrical, and still further possibilities for isomers exist if the dienophile is unsymmetrical, e. g. acrylic acid, ($H_2C{=}CH\text{-}COOH$). In this case, even with *alpha*-eleostearic acid two isomers are capable of existence, e. g.



$R = -C_4H_9$ $R' = -C_9H_{16}COOH$

Four possible addition products of *beta*-eleostearic acid with acrylic acid are possible. An extensive study of Diels-Alder addition products of tung oil derivatives has been made by Bickford and coworkers (21), and some of these products have been extremely useful in elucidating the structure of the eleostearic acids. Derivatives which have been prepared include those obtained by the addition of such dienophiles as acrylic acid, maleic anhydride, acrylonitrile ($CH_2{=}CH-C{\equiv}N$), and fumaronitrile ($N{\equiv}C-CH{=}C{\equiv}N$), and also various esters and hydrogenated products.

Thermal Polymerization of Eleostearic Acid. Thermal polymerization, which occurs very readily with eleostearates, doubtless involves a Diels-Alder type reaction in which one molecule of eleostearate reacts as a diene and another reacts as a dienophile (37). One possible reaction is indicated below:



There are eight possible stereoisomeric forms of this dimer. Further, since this dimer still contains a conjugated system, it is capable of undergoing addition with another molecule of eleostearate to form trimer, thence to tetramer, etc. The possibilities for isomerization become extremely large. In the case of a triglyceride, such as tung oil, the possibilities of cross-linking to form large three-dimensional polymers are obvious, and it is doubtless to this that tung oil owes its ease of gelation (result of cross-linking) simply on heating.

Substitution Reactions. The reaction of the hydrogen atoms attached to the carbon chains are those normally associated with such hydrogen atoms. However, the usual substitution reactions, e. g., with halogens, cannot readily be performed on the eleostearates because addition at the double bonds takes place so readily. An exception is the reaction with oxygen to produce hydroperoxides, in addition to cyclic peroxides. This reaction occurs very readily, so readily in fact, that pure eleostearates cannot be exposed to oxygen of the air at room temperature without serious degradation. Although the precise mechanism of the "drying" of drying oils has not been established, it is probable that the peroxides and hydroperoxides thus formed are effective catalysts in promoting the polymerization of the residual products. It is, doubtless, partly because peroxides and hydroperoxides of eleostearates are formed so readily that tung oil products "dry", i. e., polymerize oxidatively, so rapidly.

It may be mentioned in passing that a process for satisfactorily stabilizing certain eleostearates by formation of their urea inclusion compounds has recently been developed. That certain straight chain compounds would form complexes with urea was discovered by Bengen (3). It is now known that these complexes comprise lattices of urea crystals in which

the straight chain compound is enclosed. The complexes are usually termed urea-inclusion compounds. Many long chain fatty acids and their simple esters, including the eleostearates, form such inclusion compounds. Since the eleostearate molecules are enclosed in urea and separated from each other, the oxygen of the air cannot initiate chain reaction polymerization, and the fatty acids are not subject to autoxidation (44). Such urea inclusion compounds (crystalline products which contain about 25% eleostearate) have not deteriorated after several years' exposure to air at room temperature (48). This procedure provides a convenient means of shipping eleostearates without taking extreme precautions to avoid contact with even traces of air.

Utilization of Tung Oil

Although tung oil has been used in the United States less than 100 years, it has been used in China for many centuries, and it is still commonly referred to as China Wood oil. The Chinese have used tung oil for waterproofing paper, cloth, leather, and masonry. Their paper umbrellas were waterproofed with tung oil. Mixed with lime and hemp, it was used in calking ships. It is reported that the Chinese mixed the oil with lime, sand, and clay to produce a mixture which hardened to a tough material used in making forts (46). Tung oil is said to have been an important ingredient of mortar used in building the great Wall of China. The oil was burned for light and to furnish soot for ink. More recently (during World War II) they have converted tung oil to a motor fuel as a substitute for gasoline and as illuminant for the millions of the lamps of China in place of kerosene (7). Tung oil is a common ingredient of Chinese lacquers. The first known reference to the use of tung oil in paints, which presently comprises by far the largest use of tung oil in the United States, occurs in the "Book of Poetry" which is a collection of Chinese folk songs compiled by Confucius more than 24 centuries ago (29).

Importation of Tung Oil. The first shipment of tung oil to the United States appears to have been in 1869. This shipment was valued at $62.00, and the total amount imported in the season 1869-70 was 381,000 pounds. Its value was not fully appreciated at first, partly because of unfamiliarity with how properly to use this unusual oil and partly because various gums and natural fossil resins were abundantly available and cheap so that there was no apparent need for tung oil. Growth of consumption of tung oil in this country was slow, and it was 14 years later, 1883-84, before imports passed the million pound mark and another ten years, 1903-04, before the five million pound mark was reached (29). After that, the growth in imports was rapid, exceeding fifty million pounds in 1910 and one hundred million pounds in 1925. Data for imports of tung oil and yearly average prices for selected years are given in Table I. It will be noted that for each of the six years, 1933 through 1938, imports exceeded 100 million pounds and averaged more than 125 million pounds. And this was during the period of the Great Depression. The peak of imports was reached in 1937 when they amounted to 175 million pounds. After that, imports declined and during World War II were negligible. After the war, large-scale imports from China were resumed, reaching a peak of nearly 133 million pounds in 1948. Imports from China again decreased, partly owing to the Civil War in China and partly to the Korean War. Since December 17, 1950, imports of tung oil from China (except Formosa) and North Korea have been excluded from entry by the Foreign Assets Control Regulations of the Treasury Department (54). These regulations are designed to prohibit trade and financial transactions with those countries.

TABLE I
IMPORTS AND PRICES OF TUNG OIL IN THE UNITED STATES IN STATED YEARS

Year	Imports mil. lbs.	Average price per lb., drums, N. Y.
1912	43	10.1
1916	58	12.0
1920	68	19.7
1924	82	15.9
1928	109	15.2
1932	76	6.3
1933	119	6.8
1934	110	8.9
1935	120	17.0
1936	135	16.1
1937	175	15.7
1938	107	13.5
1940	97	26.3
1942	8	39.6
1947	122	30.5
1948	133	24.5
1952	30	40.4
1953	23	29.3
1954	36	23.9
1955	21	25.8
1956	31	25.8
1957	29	24.7

Sources: 1912-53: Banna, A. Oilseeds, Fats & Oils, & Their Products 1903-53, U. S. D. A. Stat. Bull. **147**, 141, 165 (1954).
Imports, 1953-56: U. S. D. A. Agricultural Statistics, 1957. U. S. Govt. Print. Off., Washington, 1958, p. 167.
Imports, 1957: U. S. Bur. Census, Report No. FT-110, calendar year 1957, U. S. Govt. Print. Off., Washington, 1958.
Prices, 1953-57: Fats and Oils Situation (U. S. Agr. Marketing Service), FOS-188, 33 (Jan. 1958).

Before 1949, China was virtually the sole source of United States imports of tung oil. Since then, Argentina has become the principal source of United States imports. Paraguay has supplied most of the rest, followed by Brazil. Since 1949 total Argentine exports of tung oil have averaged 25 million pounds annually. However, the trend of exports from Argentina has been gradually upward. It exported 30 million pounds in 1956. Imports of tung oil are presently restricted by presidential proclamation. A quota, amounting to 26 million pounds annually, has been established on the amount of tung oil which may be imported into the United States during the crop years beginning November 1, 1958 and 1959 (53).

Domestic Production of Tung Oil. Domestic production, which began on a commercial scale about 1932, increased to 500,000 pounds in 1937 to 5 million pounds in the 1942 crop year, 14 million in 1946, 26 million in 1949, and a peak of 43 million pounds in 1952. Following this, production declined drastically, owing to unfavorable weather and nearly disastrous freezes, but recovered to 32 million pounds in 1956, and it is expected that 1958 production will approximate 40 million pounds. Data for domestic production of tung oil in selected years are given in Table II.

It will also be noted, from Table I, that prices for tung oil have varied widely, from a yearly average low price of 6.3 cents per pound in 1932 to a high of 40.4

TABLE II
DOMESTIC PRODUCTION AND CONSUMPTION OF TUNG OIL IN STATED YEARS

Year Beginning November	Production Mil. lb.	Consumption Mil. lb.
Average 1935-39	0.6	118.1
1942	5.2	11.5
1943	1.9	10.5
1944	8.8	21.7
1945	9.1	33.2
1946	14.4	87.1
1947	16.0	130.4
1948	17.0	107.7
1949	26.8	112.5
1950	12.3	72.4
1951	14.7	51.2
1952	43.4	49.6
1953	39.6	49.3
1954	15.2	51.2
1955	2.0	51.4
1956[1]	32.0	50.4
1957[2]	25.5	45

[1] Preliminary
[2] Partly estimated

Source: Fats and Oils Situation (U. S. Agr. Marketing Service), FOS-191, 29 (Aug. 1958).

in 1952. The Commodity Credit Corporation support price of tung oil processed from the 1958 crop (65% of parity) is 22.0 cents per pound.

Industrial Uses. Tung oil is preeminently an industrial oil; that is, it is used almost exclusively for industrial rather than for edible or medicinal purposes. It is a premium drying oil, and this application, interpreted broadly, accounts for substantially all the tung oil used in industry. The main industrial consumers of drying oils are the paint and varnish, the linoleum, oilcloth, and printing ink industries. The domestic consumption in these industries and in "other drying industries" is given in Table III. The classification, "other drying industries," includes a large number of miscellaneous industries which consume tung oil for special uses. These include brake linings for automobiles, gaskets for steam pipes, abrasives, binders, and adhesives, cleaning and polishing compounds, molding composition, putty, insulation for electric condensers and other electrical equipment, and a multitude of other specialized applications. Although the volume used in any one of these applications is small, the total reaches a considerable quantity. Some concept of the variety and number of the industrial applications of tung oil may be inferred from the fact that the Abstract Bibliography (42) lists some 800 patents which have been issued covering the diverse applications of tung oil during the period, 1875-1950, more than 400 of them in the United States alone. An additional 40 patents issued in the United States during approximately the two-year period, 1950-1952, are listed in a review of this period (40). Suggested uses covered by these patents range from abrasives and adhesives to wrinkle finishes and zinc tungoate lacquers.

Consideration of the data in Table III will show that although tung oil was at one time used in considerable amount in the linoleum and oilcloth and the printing ink industries, in recent years the use of tung oil in these industries has diminished to negligible proportions. This is due partly to replacement by other more readily available or cheaper products such as tall oil (a low-cost by-product of the paper industry) and partly to technological changes in the industries themselves.

Since 1950 approximately half of the tung oil classified as "other drying oils" in Table III was used for the production of resins (51). Tung oil is sometimes used in the production of oil-modified phthalic alkyd resins, large quantities of which are produced annually. Some impression of the effect of the addition of

TABLE III
DOMESTIC CONSUMPTION OF TUNG OIL, BY END USE, 1935-56
(IN MILLION OF POUNDS)

Year	Paint and Varnish	Linoleum and Oilcloth	Printing Inks	Other Drying Use	Total
1935	112	10	2	3	128
1936	106	7	2	4	119
1937	134	7	3	5	148
1938	82	4	2	3	91
1939	97	4	2	3	106
1940	62	2	2	1	67
1941	63	2	3	[1]	69
1942	11	[1]	[1]	1	12
1943	10	—	[1]	2	12
1944	8	—	[1]	2	10
1945	18	2	1	2	23
1946	32	[1]	1	3	36
1947	87	5	1	13	106
1948	102	9	1	18	130
1949	84	10	1	9	103
1950	92	5	1	11	109
1951	54	1	1	9	65
1952	45	[1]	1	6	52
1953	43	[1]	1	7	51
1954	42	1	1	4	48
1955	42	—	[2]	7	51
1956	44	—	[2]	7	51

[1] Less than 0.5 million pounds
[2] Not available

Source: U. S. Tariff Com., *Tung Oil*, Report to the President on Investigation No. 15 under Section 22 of the Agricultural Adjustment Act, as amended, May 1957, p. 19.

even minor proportions of tung oil may be inferred from the observation (6), "If 1.0 percent tung oil is polymerized with 99% styrene a clear, colorless resin is obtained which is unusually tough, has an impact strength five times that of pure polystyrene and is essentially insoluble in all organic solvents that dissolve polystyrene easily . . . This surprising change in solvent properties and toughness is explained on the basis of a cross-linking polymer forming, rather than a straight-chain connection as in the case of polystyrene."

The introduction of tung oil as a raw material for use in varnishes brought about important changes in the technique of varnish manufacturing processes. These changes were the result of the characteristics of tung oil which cause it to polymerize much more rapidly than the oils which had been previously used in making varnish. This greater ease of polymerizing, or "bodying," caused the varnish maker considerable difficulty when the oil was first used. Too frequently this resulted in batches which gelled in the varnish kettle. This not only resulted in loss of the materials used but also in considerable hand labor for chopping out the hard gelled resin before the kettle could be used again. When the value of the use of rosin as a means of controlling this gelation was realized (about 1907), it became possible to eliminate many of the difficulties previously experienced. Tung oil and rosin were used extensively in making spar varnish. This type of varnish had a more durable finish with better resistant and waterproofing properties than the older varnishes derived from linseed oil and imported fossil gums.

Tung oil is rarely used in the raw state because the oil dries to form a film which is opaque (frosted), wrinkled, and dull. This was, in fact, the basis for the production of wrinkle finishes which were so popular in the 1930's (50). Heating the oil produces a polymerized or bodied oil which gives a smooth, clear film. However, special care must be taken in bodying tung oil and in the preparation of tung oil varnishes. Some products which will dry satisfactorily to clear films under favorable conditions will nevertheless wrinkle or crowfoot under adverse conditions such as high humidity or noxious gases. A product which will dry satisfactorily to a smooth, clear film even under such adverse conditions is said to be "gas-proof." Temperatures of about 550° F. are required fully to "gas-proof" tung oil, but at this temperature it will set to a gel in a few minutes. The margin of safety between the conditions required to provide gas-proofness or to produce a useless gel is uncomfortably small. Numerous procedures have been developed to ameliorate this situation, particularly the use of various phenolic resins and, more recently, the use of zinc resinate (16).

As a drying oil, tung oil must compete with other important drying oils such as linseed, soybean, fish, dehydrated castor, oiticia, and tall oils. These oils are closely related in their physical and chemical properties and can be substituted for one another to some extent. Each has its special properties for which it is preferred for certain uses. Drying oils are often blended, modified, or used in conjunction with various resins to widen their applicability and increase their field of competition. The use of a particular oil in a given formulation is dependent upon various factors, including its properties, availability, price relationship, and competing resins. Generally the price of tung oil has been higher than the price of the principal competing oils. Its extensive use, despite this higher price, indicates that it is considered to be superior for certain uses, particularly in the manufacture of specialized industrial varnishes. The specifications for these varnishes can more readily be met by using tung oil because it produces a hard, quick-drying,

water-resistant film, highly resistant to acids and alkalies with good electrical properties. Some of these special varnishes are listed below:

Containers. Metal containers for foodstuffs, beverages, pharmaceuticals, tobacco, and other commodities are commonly treated with inner coatings (linings) containing tung oil. Here the tung oil imparts durability, water-proofing, acid-resistant and solvent-resistant qualities.

Lithographic Printing. Printing on metal containers, closures and advertising signs, requires a high-grade varnish having good adhesion to metal. Tung oil varnish may be used directly on the metal base as well as for a finish coat after the printing has been applied to provide a satisfactory protective film.

Insulating Varnishes. Insulating varnishes made with tung oil are used in the electrical industry for treating coils, coating cloth, making insulating tapes, and for finishing insulated wire, cables, and metallic surfaces.

Enamels. Rapid-drying enamels, composed of tung oil, together with a high-covering-power pigment, a synthetic resin, and solvent are used for production line finishing of farm equipment, machinery, and other metal products. It is recommended for stair railings, pipes, metal sash, processing machinery, and on any surface where rapid handling is necessary.

Wall Board. Considerable quantities of tung oil have been used in "tempering" wall board. When a porous wall board is impregnated with a tung oil composition, a hard moisture- and abrasion-resistant finish is obtained.

Constant research work conducted by industry, The Tung Research and Development League sponsored by tung growers, and laboratories of the United States Department of Agriculture has resulted in new and improved processing methods and new and improved products utilizing tung oil and simple derivatives of tung oil such as the eleostearic acids and their methyl esters. Research currently is emphasizing especially the utilization of tung oil, and particularly the eleostearic acids derivable from tung oil, in applications other than surface coatings. Proposed applications of such products include plasticizers for polyvinyl chloride plastics, fugitive emulsifiers for agricultural sprays, and fire retardant products.

Tung Press Cake

Tung press cake is one of the principal by-products of the production of tung oil from tung fruit. Roughly one and one half pounds of press cake are produced for each pound of oil expressed. The cake, or meal, contains about 27% of crude protein, and is used chiefly as a fertilizer. The high nitrogen content would indicate that it might be of value as a stock feed, but it contains toxic materials. Commercial press cake is toxic and unpalatable to rats, young chicks, and cattle. It contains two types of toxic components, one of which is heat labile but insoluble in the usual organic solvent such as alcohol or mineral spirits. The other is heat stable but soluble in alcohol and benzene. Thus it appears possible to reduce the toxicity of tung meal by extracting it with solvent followed by heating to a temperature above 100° C. Two different nitrogen-free materials which are highly toxic to young chicks have been isolated from the soluble toxic material present in tung press cake (28).

Tung nut shells contain nearly 45% lignin. A study of the preparation of vanillin from tung nut shells has been reported (39). The maximum yield of vanillin, as determined analytically, amounted to 3.2% of the weight of the

shells, but the amount actually isolated was only 1.5%. The process has not been commercialized.

Plastics have been prepared by substituting tung press cake for common fillers in phenolic plastics. Molded objects made of these plastics have good appearance but absorb excessive amounts of moisture when immersed in water (32). These products are not sufficiently superior to those made from other similar competing materials to warrant commercial production.

Tung Hulls

Tung hulls constitute about 50% of the tung fruit. They contain about three percent potash and small amounts of nitrogen and are therefore sometimes used as a mulch in the groves and as a conditioner in mixed fertilizers. The use of hulls in commercial fertilizers is limited because of difficulties resulting from spontaneous heating in storage and during transit. Hulls containing more than 17% moisture were reported to heat spontaneously, while hulls with 15% or less moisture content did not display this difficulty (24). Heating is accelerated and prolonged by aeration. Hulls containing 12.3% moisture have a calorific value of about 7,160 B. T. U. per pound which corresponds to 8,300 B. T. U. for dry hulls (24), a value slightly less than for wood. Tung hulls are sometimes burned as fuel under boilers using specially constructed grates. Hulls can also be burned and the ash used in fertilizer. One plant does this commercially.

Hulls from green fruit have been reported (32) to contain about 67 mg. of ascorbic acid (Vitamin C) per 100 grams. Hulls from ripe fruit are lower in Vitamin C content. Hulls from ripe fruit contain four to seven percent of a tannin-like material, but this product had no value for tanning leather. Tannin-extract from pecan hulls has been used in oil-well drilling muds to control viscosity of the mud, and the use of tung hulls for this purpose has been proposed.

Looking Forward

Obviously tung oil must contribute the greatest proportion of the value of the tung crop since the by-products, press cake and hulls, can afford only a small return. Used as a drying oil, tung oil must compete with other drying oils. Chemical technology, through development of newer processes such as ester interchange, isomerization, and liquid-liquid extraction, is making the various drying oils more nearly equivalent and interchangeable. This tends to narrow the price spread between them. Further, competitive pressure from synthetics based upon petrochemicals or coal will almost certainly increase and will doubtless be felt most strongly in the premium products now best served by tung oil. New industrial outlets are needed. Development of new uses outside the protective coatings field is essential. For this the chemical industry offers a particularly inviting field. Billions of pounds of synthetic organic chemicals are produced annually for use in plastics, plasticizers, and lubricants. Chemical research now under way is directed toward modification of tung oil, taking advantage of the unusual configuration present in the eleostearic acids, to produce chemicals not easily prepared from other drying oils or petrochemicals. Chemical modification of tung oil to produce materials with novel and desired properties should provide a bright prospect for the tung industry.

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Furcellaran, A Versatile Seaweed Extract [1]

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Introduction

Up to recent times users of seaweed hydrocolloids have had their choice of only three types: carrageenan, algin, and agar. Now comparative newcomers have become increasingly important. One of the most promising of these is furcellaran, the extract of the seaweed species *Furcellaria fastigiata* (Fig. 1). This plant is found principally in Danish waters where its collection and utilization forms the basis of the Danish seaweed industry.

Figure 1

Furcellaran extract, with properties reminiscent of both carrageenan and agar, is effective both as a gel-former and stabilizer. An important advantage in its use is that it is readily soluble at 160° F. in contrast to agar which requires boiling or superheated water for solution. When the allied nations were cut off from their supply of Japanese agar during World War II, it became necessary to find substitutes, and attention was directed to locally available materials. By the end of the war the uses and advantages of furcellaran had become so well established that production and sales have been steadily rising.

Present Danish production of extract selling for about $1.10 per lb. is about 500 tons per year. Supplies of weed are adequate to increase this figure if the demand should warrant it. The demand for the weed has been increasing yearly since 1946, as shown in Table I, and is likely to continue as new uses and properties are discovered (1, 2).

TABLE I
FURCELLARAN PRODUCTION

Year	Production (pounds)
1946	65,000
1948	131,400
1950	157,600
1952	360,000
1954	520,000
1956	740,000
1958*	1,000,000
1960*	1,200,000

* Estimates

Harvesting and Extraction

The weed is gathered relatively easily. Large masses of free-floating weed are gathered by small vessels, using large trawling nets (Fig. 2). The weed is loaded directly into the cargo hold and about 100 tons of wet weed are collected per day in this manner. When the ship

Presented in Chicago before Division of Carbohydrate Chemistry at 134th National Meeting of American Chemical Society in September, 1958.

Figure 2

reaches port, the weed may be allowed to bleach in the sun or may be loaded onto trucks which carry the weed to the factory. The weed is dumped into huge outdoor bins where alkaline preservation is immediately performed. After two to three weeks' storage the weed is neutralized and thoroughly washed. The material is treated with boiling water to extract the furcellaran, filtered or centrifuged, and a potassium salt is added. This causes gelation upon cooling. The gel is frozen, thawed, and pressed to remove the bulk of water and impurities. The residue is then bleached with hypochlorite solution, dried in a tunnel dryer, ground to 100 mesh, and packaged. By this and similar techniques, 40 kilos of *Furcellaria* weed are made to yield 1 to 1.5 kilos of furcellaran.

The principal properties are as follows: it is a fine, white, odorless, free-flowing powder, soluble in 75° C. water; it is soluble in boiling milk and forms firm

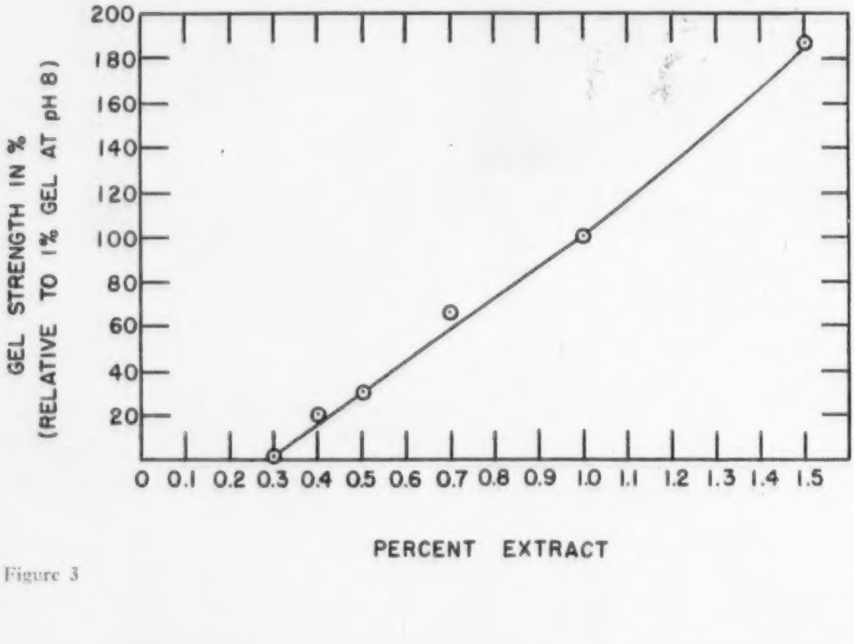

Figure 3

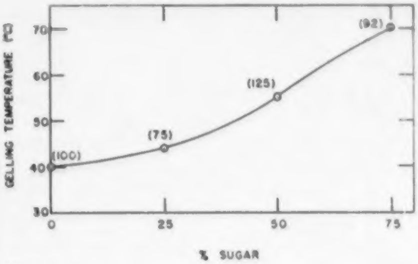

Figure 4

gels upon cooling. Solutions can be autoclaved without degradation and are moderately resistant to acid hydrolysis. The gels are about as strong as agar and six to seven times as firm as gelatin gels. Gel strength increases with furcellaran level in a strictly linear manner as shown in Fig. 3. Sugar raises the gel temperatures in an almost linear manner. The numbers in parentheses refer to gel strengths (Fig. 4).

Gel strength is highly dependent upon pH and reaches a maximum at about pH 8. The presence of other materials such as sugar may broaden the range considerably and even shift the pH optimum (Fig. 5). Like carrageenan, hypnean, and other extractives containing a half sulfuric acid ester, the extract forms gels of greater firmness when small amounts of potassium chloride are substituted for equal weights of furcellaran, as shown on the curve in Fig. 6. The point "X" indicates the gel strength obtained by adding 0.10% potassium chloride to 1% furcellaran without removing an equal weight of the extract.

Furcellaran forms extremely viscous solutions even in comparatively low con-

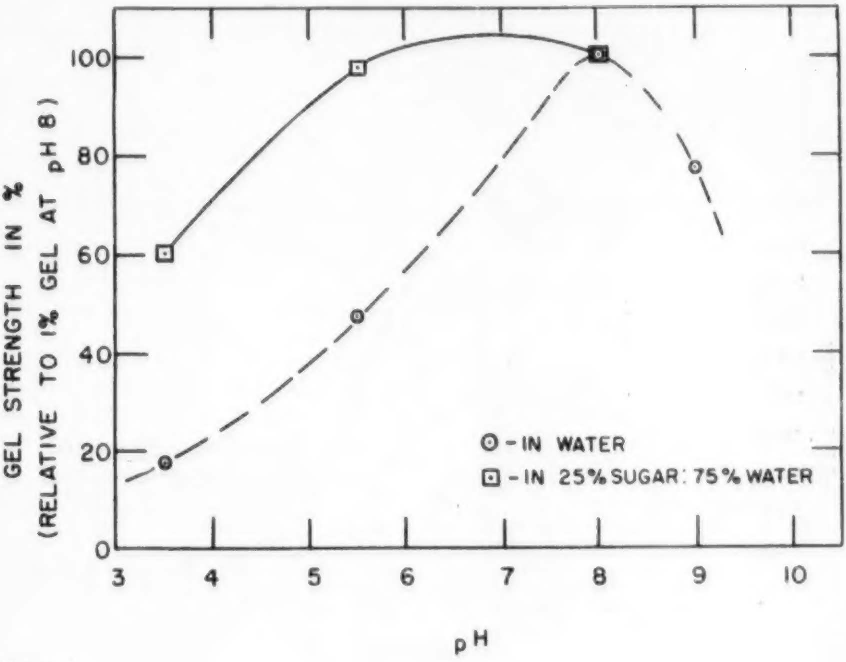

Figure 5

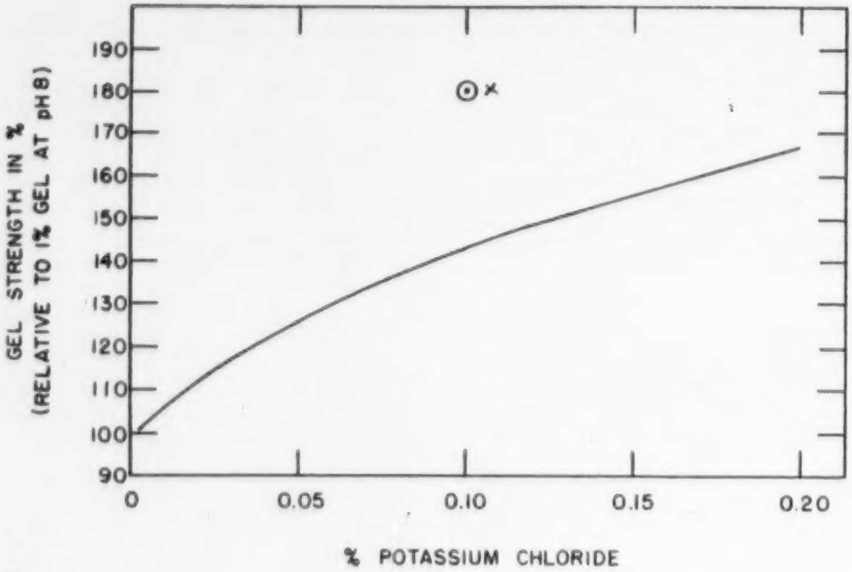

Figure 6

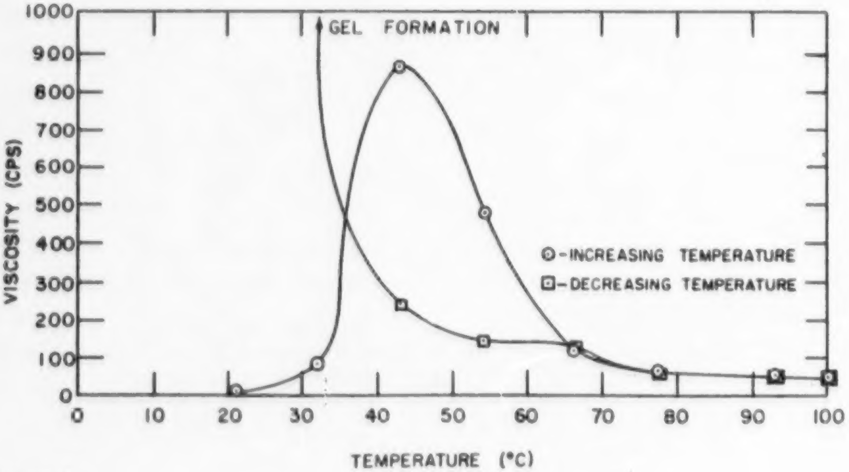

Figure 7

centration. If a 1.5% furcellaran solution is heated, considerable thickening occurs at about 37° and the viscosity continues to increase as the temperature rises. A maximum viscosity occurs at 43°, and further heating causes the viscosity to drop progressively. By the time the temperature reaches 50, it has thinned considerably, and at the boiling point, the viscosity is quite low. Upon cooling, the viscosity increases steadily until the gelling point is reached (Fig. 7) (3, 4).

Structure (5, 6, 7, 8)

The extract is a half sulfated galactose ester of molecular weight 20,000 to 80,000 and may be very similar to the extract of other seaweeds such as hypnean, the extract of *Hypnea musciformis*. It resembles carrageenan but has a lower sulfate to galactose ratio, about one sulfate to each three to four sugar units. In comparison, lambda carrageenan has about one sulfate per sugar unit and kappa carrageenan has about one sulfate per two sugar units (9). Recent evidence shows that 3, 6-anhydrogalactose and a uronic acid may be present (10).

Furcellaran has other sugars present besides galactose, as shown in Table II. The total reducing sugar content is about 30% to 50%. In addition, about 5.7% cellulose is found. The plant contains quantities of floridoside and starch which it uses as reserve carbohydrates. The quantities of these are small in the spring but are built to as much as 36 parts starch and 8 parts floridoside per 1,000 parts of fresh plant in the summer months.

TABLE II
SUGAR UNITS FOUND IN HYDROLYZED FURCELLARAN

D-galactose	13.9%
L-galactose	4.6
Glucose	5.1
Xylose	3.7
Fucose	small amount
Mannose	none
Arabinose	none
Galacturonic Acid	none

Uses

The present limits to the greater use of furcellaran are its high viscosity, which can sometimes be objectionable, and local legislation, which sometimes requires the use of pectin or gelatin in a product and does not permit other gelling agents. In spite of this, the uses of furcellaran are quite numerous. It is used in milk puddings, jams, jellies, marmalade, imitation jams and jellies, diabetic or dietetic products, meat or fish preservation, tooth paste, pharmaceuticals, appetite reducing diets, culture medium, unboiled icing bases, bakers' jellies and as a bacteriocide. As a bacteriocide it has been shown to be effective against *Bacillus pumilis* and possibly effective against *Pseudomonas fluorescens*, *Bacillus subtilis-30*, and *Pseudomonas pyocyanea*. This places its activity midway between relatively potent bacteriocides as *Laminaria digitata* and some *Polysiphonia* species and very weak bacteriocides as *L. saccharina* and *Fucus vesiculosis*.

These illustrate some of the present applications of this versatile product, but new usese are discovered almost daily. More detailed information on furcellaran appears in the "Lesser Known Seaweed Extracts" chapter of the book INDUSTRIAL GUMS, published by Academic Press and edited by R. Whistler.

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Utilization Abstract

Ylang ylang for Perfume. *Cananga odorata*, Annonaceae, produces flowers of great importance to the perfumer. The species is a tree from 60 to 80 feet tall, native to China and Burma, but the areas of its commercial importance today are the islands of Réunion, Nossi Bé, Madagascar, and the Comoro Islands. Flowers occur throughout the year but are seasonally abundant.

Besides its use in perfumery ylang ylang is used medicinally. In cold-blooded animals, if administered internally, it causes general paralysis, and in warm-blooded animals it causes a reduction in blood pressure and slows circulation. *C. odorata* has been used as a substitute for quinine in the treatment of malaria. Malaysians use a pomade prepared from the flowers rubbed on the skin or hair to prevent or cure fever and to guard against skin disorders.

Harvesting the flowers for perfume purposes is done in the early morning, and great care is taken to prevent wilting or bruising. The oil obtained by steam distillation, a clear yellow to golden yellow liquid, is divided into three grades. Ylang ylang oil is complex, and from it a number of perfume materials is extracted. These extracts may be used as adjuncts in the formulation of several different perfumes—jasmin, lilac, wallflower, etc.

Leonard Stoller in *The Givaudanian, April, 1959.*

DJR

BOOK REVIEWS

The Orchids, a Scientific Survey. Edited by Carl L. Withner, The Ronald Press Company, N. Y., N. Y., 648 pp. $14.00.

Editor Withner has done a monumental piece of work in collecting and arranging all the widely scattered scientific information on one of the world's most fascinating plant groups: the orchids. While this book is basically a scientific work it should, nevertheless, provide the orchid culturist with a valuable reference and guide as many horticultural aspects of the Orchidaceae are well covered.

In the introductory chapter, Withner traces the cultural history of the orchid. This is followed by an excellent chapter on the history of orchid classification by Charles Schweinfurth. Mrs. Adams' section on variation in the Orchidaceae, with the accompanying linograph drawings gives an excellent account of orchid variation. Some of her remarks concerning the methods and materials employed by modern botanists are very provocative. Other sections deal with orchid anatomy, cytology, and embryology. The chapter on hybridization and inheritance by Lenz and Wimber is very well done. The list of intergeneric orchid hybrids is valuable and the discussion of flower-color inheritance is very comprehensive. In concluding their chapter these authors call for the formation of an "Orchid Genetics Newsletter" which would collect and disseminate, on a world-wide basis, cyto-genetical data on the Orchidaceae. Withner's chapter on orchid physiology covers such topics as seeds, seed germination, and reproductive physiology. Of special interest to some will be the chapter by Burgeff (and by the way this chapter is a Botanical classic) on the Mycorrhiza of Orchids. Other chapters on the effects of photoperiod and temperature an the orchids, the diseases of orchids, and orchid pests are also included. Appendix I, the key to the orchids, largely Schlechter's system, is not too stimulating. Appendix II is a much needed list of orchid chromosome numbers. Appendix III is particularly valuable as it brings together in concise form the many orchid culture media and nutrient solutions. Appendix IV covers the smear techniques for counting chromosomes in the orchids.

R. J. GILLESPIE

Some Plants Used by the Bushmen in Obtaining Food and Water. R. Story. Union of South Africa, Dept. of Agr., Div. of Bot. Bot. Surv. Mem. No. 30, 1958. 115 pp. 52 text pages and 62 illustrations. 13 shillings.

Results of a survey of food and drink plants of the Bushmen made from June to September, 1955, on an expedition sponsored by Harvard-Smithsonian-Peabody Museums. The area investigated was the Bechuanaland Protectorate and Southwest Africa. A map of the area studied is included.

In this report Dr. Story gives full acknowledgement to the Bushmen for their ability to live in an area almost devoid of surface water. Their knowledge of the various plants useful for both food and water is extensive, and their ability to distinguish between useful or harmful plants is remarkable.

There is a short discussion of the orthography of the Bushmen languages, carefully checked by linguists. A key to the various food plants, based on the vegetative parts, is provided.

Since the expedition was made in the winter months, some of the annuals used by the Bushmen were not observed. Some of the plants were sent to Pretoria, grown in gardens, and photographed there.

For each included species there is a good morphologic-ecologic description, methods of preparation, and the various Bushmen names.

Of the plants mentioned more belong to the Asclepiadaceae than to any other family.

It is doubtful that most of the plants used by the Bushmen would be of interest as food plants by more sophisticated societies. There are some, however, which might well be considered as interesting and useful in other desert areas of the world.

D. J. ROGERS

The Staple Food Economies of Western Tropical Africa. Bruce F. Johnston. Stanford University Press xi + 305 pp. 1958. $6.00.

This is a publication of the Food Research Institute, Stanford University. It is one of a group of studies in tropical development.

Bruce F. Johnston has done an admirable job of summarizing the present knowledge of African staple food crops. His particular emphasis is on "physical economic and social factors which seem most pertinent in explaining the considerable variation in the relative importance of the staple crops, not only as among territories but also as among smaller districts." He has drawn upon a very extensive number of writers and articles and has been able to sift various reports for their best contributions in an area where there is a dearth of information. In the ten chapters he has given a lucid picture of the various aspects of the crops—their use, their culture, their economics, their value as foods, and their social acceptance.

Some rather interesting statistics have been gathered in well-presented tabular form, and several maps show distributions of root and grain crops. Johnston shows the African's tremendous dependency on root crops such as manioc, which is the most widespread but generally the least desirable, and yams, which enjoy a higher esteem among the various peoples. Maize is one of the strongest grains, with rice, sorghums, and millets following in importance.

The book demonstrates that the African farmer is far from being as inelastic in his choice of food materials as many non-Africans have painted him. The fact that two western hemisphere crops are the main staples for much of western Africa is fair proof of this. The African is not as backward as has been assumed. Economic fact rather than social backwardness accounts for failure to shift from one culture to another, Schemes to improve, increase, or change from one crop to another have failed miserably, not because of the lack of incentive on the African's part but because of the failure to provide the right economic situation for the change. Poor transportation, lack of adequate markets, insufficient credit to the farmer, no means of storage of surplus (if any), etc., are the reasons set forth in this book. The data supporting such arguments are strong and well documented.

Johnston's discussion of the distribution of the various crops shows a tremendous amount of labor in sifting the scattered literature. He does not make the mistake of many authors who, after a short visit to a country, become "authorities" thereon. It is interesting to note that manioc and maize have spread very rapidly to many areas within the past fifty years, although the crops were known to Africans since the introduction by the Portuguese and Spanish. There are obvious reasons for increasing dependency on manioc—ease of cultivation, capacity to produce at least a small return on impoverished soils, resistance to drought and locusts, and others.

It is likely that more and more emphasis will be put on the production of grain crops, particularly paddy rice. Many lowland swamps have not been utilized, and these can produce greater yields than upland rice on lands which have become impoverished. The problems of handling harvested rice are being met by the use of machinery, first hand-powered and then power-driven as natives become more accustomed to machine methods.

Johnston recognizes the importance of more intensive research at all levels. Perhaps he does not recommend with sufficient emphasis the important role of basic research on present-day crops, but in this he is not alone. Certainly there is need for all levels and kinds of research from purely agricultural to purely economic. This book is strongly recommended by the reviewer for anyone with any interest in western tropical Africa. It should be compulsory reading for all members of the diplomatic service, and economists will benefit by this masterful survey.

D. J. ROGERS

Annual Review of Plant Physiology. Edited by L. Machlis and J. G. Torrey. Vol. 10 vi — 483 pp. 1959. Annual Reviews, Inc., Palo Alto, Calif. $7.00.

Each year a reviewer of the Annual Reviews of Plant Physiology must remark, with complete honesty, that the volume under consideration is a worthy successor to its

predecessors in the series. This year the Editors have again presented a balanced collection of articles which is of a very high order.

Chapters on protein, fat, and carbon metabolism are balanced by papers on mineral nutrients, nitrogen nutrition, and respiration. The interrelations between structure and function are explored in chapters on chloroplasts and photosynthesis; chapters on the chemical regulation of growth are in proximity to others on tropisms and on lignins; and chapters on mineral nutrition counterpoint others on salt uptake and foliar absorption. Special papers on viruses, chemotherapy and on the general physiology of the pine tree round out the book.

There is, as always, a tendency for authors to prepare anotated bibliographies rather than attempting the more difficult task of synthesis. Other authors have succumbed to the temptation to use their alloted space as a forum for personal grievances. These faults do not, however, detract from the book.

A critique of any of the contributions would, of course, be out of order in this review. Yet the chapters on leaf proteins by N. E. Pirie, fats by P. K. Stumpf and C. Bradbeer, and carbon by M. Gibbs should be singled out for special mention. They represent models for papers in such a review volume. The Editors should be congratulated on the representation given to the "practical aspects" of Plant Physiology. Neither pure or applied biology exist in vacuo and the intergradations between these artificial extremes are here for all to see.

RICHARD M. KLEIN

INDEX, VOLUME 13, 1959

Abbreviations. **A.** = abstract; **Art.** = article; **B.R.** = book review.

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